Identification of Unknowns

Lab 2

• Work with a partner (part 1) and individually (part 2)
• Pre-lab must be completed before lab session.
• Aim of experiment is to use chemical properties of a substance for identification
• Use observations to draw conclusions
• All substances have mass and therefore must be composed of atoms.
• How the atoms are assembled in the substance determines their chemical and physical properties.
Chemical Properties

- All matter has properties.
- There are two basic types of properties that we can associate with matter.
- These properties are called **Physical** properties and **Chemical** properties.

**Physical properties:** Properties that do not change the chemical nature of matter. (color, smell, freezing point, viscosity).

**Chemical properties:** Properties that do change the chemical nature of matter. (Heat of combustion, reactivity with water, pH).
• Matter can be analyzed and classified by physical or chemical processes.

• If we have a sample of matter and can find a **physical process** such as evaporation, magnets, color etc. to separate it then the sample is a "mixture".

• Furthermore if the sample is a mixture of solids and liquids (e.g., sand and water) etc. or two or more liquids that don't mix (e.g., oil and vinegar) then the mixture is "inhomogeneous". Otherwise the sample is a "homogeneous" mixture.

• If there is no physical process that will separate the sample then the sample is a "pure" substance.

• If a chemical process such as combustion or oxidation breaks the substance down to its constituent atoms then the substance is a "compound"(e.g., salt, sugar, water).

• Otherwise the substance is an "element" (e.g., copper penny, aluminum foil). Compounds are made up of molecules or salts. elements are made up of single types of atoms.
What is a chemical reaction?

• A chemical reaction is a process by which one set of substances called reactants is converted to a new set of substances, called products.

• Physical evidence often indicates a chemical reaction:
  – A color change
  – Formation of a solid
  – Evolution of a gas
  – Evolution or Absorption of Heat
Reaction Types

• When water is the solvent for a reaction, the reaction is said to occur in aqueous solution, (Any solution in which water (H₂O) is the solvent.) which is denoted by the abbreviation \((aq)\) following the name of a chemical species in a reaction. Three important types of reactions in water are precipitation, acid-base, and oxidation-reduction reactions.
Precipitation Reactions
In a precipitation reaction, an anion and a cation contact each other and an insoluble ionic compound precipitates out of solution. For example, when aqueous solutions of silver nitrate, AgNO₃, and salt, NaCl, are mixed, the Ag⁺ and Cl⁻ combine to yield a white precipitate of silver chloride, AgCl:

\[
\text{Ag}^+ (aq) + \text{Cl}^- (aq) \rightarrow \text{AgCl} (s)
\]

Acid-Base Reactions
When hydrochloric acid, HCl, and sodium hydroxide, NaOH, are mixed, the H⁺ reacts with the OH⁻ to form water:

\[
\text{H}^+ (aq) + \text{OH}^- (aq) \rightarrow \text{H}_2\text{O}
\]

HCl acts as an acid by donating H⁺ ions or protons and NaOH acts as a base, furnishing OH⁻ ions.

Oxidation-Reduction Reactions
In an oxidation-reduction or redox reaction, there is an exchange of electrons between two reactants.
Two important principles apply when writing balanced equations for reactions between species in a solution:

- The balanced equation only includes the species that participate in forming products.
- For example:

\[ \text{AgNO}_3 \text{ (aq)} + \text{NaCl} \text{ (aq)} \rightarrow \text{NaNO}_3 \text{ (aq)} + \text{AgCl(s)} \]

The \( \text{NO}_3^- \) and \( \text{Na}^+ \) ions are not involved in the precipitation reaction and do not need to be included in the balanced equation.

- The total charge must be the same on both sides of a balanced equation.
- Note that the total charge can be zero or non-zero, as long as it is the same on both the reactants and products sides of the equation.
Solubility of Salts

- All compounds of the alkali metals are soluble
- All salts containing NH$_4^+$, NO$_3^-$, ClO$_4^-$, and C$_2$H$_3$O$_2^-$ are soluble
- All chlorides, bromides, iodides are soluble except when combined with Ag$^+$, Pb$^{2+}$ an Hg$_2^{+2}$
- All sulfates are soluble except those of Pb$^{2+}$, Ca$^{2+}$, Sr$^{2+}$, Hg$_2^{2+}$ and Ba$^{2+}$

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Insoluble Salts

• All metal hydroxides and oxides are insoluble except those of group 1A and of Ca, Mg and Ba.
• When metal oxides do dissolve, they react with water to form hydroxides. The oxide ion $O^{2-}$, does not exist in water.
• All salts that contain $PO_4^{3-}$, $CO_3^{2-}$, $SO_3^{2-}$ and $S^{2-}$ are insoluble, except those of group 1A and $NH_4^+$. 
Lab Procedure

• The aim of the experiment is to match the behavior of chemical solutions with the formulas of the chemicals that are dissolved in those solutions.
• You will have to look at the formulas of those chemicals and infer what kinds of chemical reactions and chemical properties those chemicals will have.
• You will also have to observe the reactions of the solutions themselves and match them with the predictions you make based on the formulas.
Useful Information

Acid Formulas

• $H^+$ in a formula or equation indicates an acid.
• HCl is the formula for hydrochloric acid. Hydrogen with chlorine or any other halogen or sulfur makes an acid.
• Also, chemicals with formulas like HXO where $X$ is nonmetal are generally acids.

Acid Properties

• Two convenient properties of acidic solutions are they change the color of litmus paper from blue to red.
• Acidic solutions will also change the color of pH paper to various shades of red and orange that correspond to pH values of less than 7.
**Base Formulas**

- Bases can be recognized by their formulas.
- The hydroxide ion is a base. Chemicals with formulas like MOH where M is a metal are bases. Ammonium hydroxide is also a base, as is ammonia.

**Base Properties**

- Litmus paper will turn from red to blue and phenolphthalein will turn pink in the presence of basic solutions. pH paper will turn to various shades of blue and green with basic solutions.
Reaction of Ammonium Ion

- If you have an ammonium ion in a compound and you add base (OH$^{-}$ ion) to it, you will form NH$_4$OH, which will decompose to give NH$_3$, which comes off as a gas.
- In equations this can be indicated by an upwards pointing arrow.
- Sometimes, no bubbling will be observed, but you should may smell the ammonia.
- In some cases it is necessary to warm the solution to help force the NH$_3$ into the gaseous state.
- The presence of ammonia vapor can be detected by its reaction with wet red litmus paper held above the test tube (not in the solution.)
A useful reaction is the reaction of carbonate and bicarbonate ions with acids. If a solution contains carbonate ($\text{CO}_3^{2-}$) or bicarbonate, it can react with acids to form $\text{H}_2\text{CO}_3$, which then decomposes to give off carbon dioxide gas. Bubbles of gas will be observed.
Example

\[ 2\text{HCl}(aq) + \text{BaCO}_3(s) \rightarrow \]

- First thing to consider is what the products will be?
- This is a metathesis reaction (double displacement, ‘swop partners’)
- Note the carbonate anion. HCl is an acid, acid + CO\(_3^{2-}\) = CO\(_2\)(g) evolved
- Products will be BaCl\(_2\)(aq), CO\(_2\) (g) and H\(_2\)O(l)
Precipitation Reactions

• A more general kind of reaction, but still very useful, is the precipitation reaction.

• If you use the complete formula for each compound, then the precipitation reaction can be viewed as a double displacement reaction in which one of the products happens to be insoluble in water.

• You start with two compounds which are both soluble in water and by mixing them together, you form a compound which is insoluble in water.

• Because it is insoluble it will form a solid and drop out of solution.
• This type of reaction will be used extensively, along with the solubility rules in the following way:

• Select a pair of compounds to work with. Use the formulas of the compounds to predict what the products of a reaction would be by completing and balancing the equation.

• Then determine whether the products are soluble or insoluble in water by looking at the solubility rules.

• If one of the products is insoluble, then you can predict that a precipitation reaction will take place when the solutions are mixed.
Example

• As an example of how you would go about doing this experiment.
• You are given 3-solutions numbered 1, 2 and 3, and are told that $\text{H}_2\text{SO}_4$, $\text{CaCl}_2$ and $\text{NaCl}$ are in solution in those three bottles.
• From the formulas, 1 acid should be identified.
• The solutions could be tested with pH paper. From that test it was found that solution #1 has a pH of 6; solution #2 has a pH of 2; and solution #3 has a pH of 7.
• Using this information it can be solution #2 is distinctly acidic because its pH is much less than 7. So solution #2 must be $\text{H}_2\text{SO}_4$. 
• Once one solution has been identified it can be used to help identify the others.
• The solutions can be mixed, and the reactions can be observed.
• For example, when solution #1 and solution #2 are mixed together, there is no reaction.
• When solution #1 and solution #3 are added together, there is no reaction.
• But when solution #2 is added to solution #3, there is a white precipitate.
Experimental Observations

- #2 + #1  no precipitate
- #2 + #3  precipitate

- Solution #2 is known to be H₂SO₄.
- Using the formulas, we can use the idea that precipitation reactions are a type of double displacement reaction.
- Solution #3 might be CaCl₂ or NaCl.
- The products of these reactions are HCl + CaSO₄ and HCl + Na₂SO₄.
- We know that HCl is soluble because the solubility rules say that all chlorides are soluble except AgCl, PbCl₂ and Hg₂Cl₂.
Predictions Using Formulas

- $\text{H}_2\text{SO}_4 + \text{CaCl}_2 \rightarrow 2 \text{HCl} + \text{CaSO}_4$ (insoluble)
- $\text{H}_2\text{SO}_4 + 2 \text{NaCl} \rightarrow 2 \text{HCl} + \text{Na}_2\text{SO}_4$ (soluble)

Experimental Observations

- #2 + #1 no precipitate
- #2 + #3 precipitate

- The precipitate formed must be one of the other compounds.
- If you look at the solubility rules, you'll see that the only insoluble sulfates are those of barium, calcium and lead.
- Therefore, the precipitate must be calcium sulfate, so solution #3 must have been calcium chloride, because that provided the calcium that reacted with the sulfate to form the white precipitate.
- That also tells us that solution #1 must be sodium chloride.
Questions to consider before lab

• What is a physical property?
• What is a chemical property?
• How do you write chemical equations?
• Before you write an equation, what must you know?
• What observations might suggest a chemical reaction has occurred?
• What is a precipitate?