EXPERIMENT 10:
DOUBLE REPLACEMENT REACTIONS

Introduction: You will study double displacement reactions using a small-scale method and predict the products of double displacement reactions.

Background: You will combine two water solutions, each containing positive and negative ions. Consider this generalized reaction between two ionic compounds:

$$AB + CD \longrightarrow AD + CB$$

where A, B, C, and D all exist as ions in solution. Will a reaction happen, and if so, what will be the products? Each of the positive ions **could** combine with the negative ion of the other compound, i.e. A^+ and D^- and C^+ and B^-. The formation of a precipitate, the evolution of a gas, and a temperature change all give evidence of a reaction. If we observe any one of these three phenomena we can conclude that a reaction has happened. It may help to look at a few examples.

Example 1: Solutions of sodium bromide and potassium nitrate are mixed. The predicted equation for this reaction would be:

$$\mathbf{NaCl(aq) + KNO_3\,(aq) \longrightarrow KCl\,(aq) + NaNO_3(aq)}$$

Does a reaction happen? To answer this question we look at the products. Is either one an insoluble compound (we can get this information from a solubility table) giving a **precipitate,** or is either one a **gas** or producer of gas, or would a **temperature change** be predicted? No, No, No. Therefore, no reaction happens; this is simply a mixture.

Example 2: Solutions of sodium chloride and silver nitrate are mixed. The predicted equation for this reaction would be:

$$\mathbf{NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + NaNO_3(aq)}$$

Does a reaction happen? Again we look at the predicted products. Is either one an insoluble compound (check solubility table) giving a precipitate, or is either one a gas or producer of gas, or would a temperature change be predicted? AgCl is an insoluble salt and would precipitate. Therefore, a reaction happens.

Example 3: Solutions of sodium carbonate and hydrochloric acid are mixed. The predicted equation for this reaction would be:

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2CO_3(aq)$$

Does a reaction happen? Again, we look at the products. Is either of the products an insoluble compound, or a gas or producer of a gas, or would a temperataure change be predicted? No. **Yes!** No? Carbonic acid (H_2CO_3) is an unstable compound and decomposes into carbon dioxide, a gas, and water. Therefore, $CO_2(g)$ and $H_2O(l)$ should be written in the equation, which then becomes:

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(aq) + H_2O(l)$$

Example 4: Solutions of sodium hydroxide and hydrochloric acid are mixed. The predicted equation for this reaction would be:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(liq)$$

Does a reaction happen? NaCl and H_2O are soluble, so no precipitate. Neither is a gas or producer of gas. If we touched the container it feels warm. The evolution of heat is evidence of a chemical reaction. The hydrogen ions (H^+) from the acid and the hydroxide ion (OH^-) from the

base have combined to form water. This reaction is called a neutralization reaction and the formation of water is always exothermic. Formation of
other molecular compounds like. acetic acid ($HC_2H_3O_2$), oxalic acid ($H_2C_2O_4$), nitrous acid (HNO_2), and phosphoric acid (H_3PO_4) give similar evidence of reaction.

In summary, we expect a reaction to happen:

1. if a precipitate (slightly soluble or insoluble compound) is formed,
2. if a gas or gas producing compound (H_2CO_3, H_2SO_3 or HNO_2) is formed, or
3. if a slightly ionized compound (water, weak acid or base) is formed.

Materials needed

Equipment	Chemicals (in small dropper bottles)
Magnifying glass 24-well plate	0.1 M KNO_3,, 0.1M $AgNO_3$, 0.1 M Na_2CO_3, 0.1M $BaCl_2$ 0.1 M $CuSO_4$, 0.1M iron(III) chloride, $FeCl_3$, 0.1M NaCl 0.1 M NH_4Cl, 0.1M $Zn(NO_3)_2$, 0.1M $CaCl_2$, 6M HCl, 3 M H_2SO_4, 6 M nitric acid (HNO_3), 10% sodium hydroxide (NaOH)

Procedure

1. Obtain the equipment listed above from your instructor or from the stockroom.
2. Assemble a set of chemicals in dropper bottles and obtain a 24-well-plate
3. Each square in the report sheet indicates the two chemicals to be mixed. Place 8 drops of each indicated chemical in the well. Write observations on the **report sheet.** Note the formation of any precipitate or gas. If there is no evidence of a reaction, test the well with a thermometer and if you notice a ΔT (temperature change) greater than 1^oC, you can take this as evidence of a reaction. Record ΔT and the direction of change, up or down.
4. Clean up your bench area, return equipment to your instructor or to the stockroom and return chemicals to **REAGENT CENTRAL.** Check the **Safety and Waste Disposal** section for instructions about waste.

Safety and Waste Disposal

Safety: Acidic and basic solutions can cause skin discomfort. If you get any of these solutions on your skin, wash with plenty of water. The silver nitrate solution will cause a discoloration of your skin but is not dangerous. Safety Goggles must be worn at all times in the laboratory.

Waste Disposal: Silver, iron, copper and barium should not be disposed of in the sink. Drain the solutions into a waste container in the hood and rinse the well plate with your wash bottle. After the initial rinse, the well plate should be thoroughly washed and rinsed at the sink.

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Write the complete equation for each mixture in which there was a reaction. A complete equation is balanced and contains labels, i.e. (s), (l), (g), or (aq). Write "no reaction" if no reaction was observed.

	OBSERVATIONS	**Equations for Reactions**
1		$NaCl_{(aq)} + KNO_{3\ (aq)} \rightarrow$
2		$NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow$
3		$Na_2CO_{3(aq)} + HCl_{(aq)} \rightarrow$
4		$NaOH_{(aq)} + HCl_{(aq)} \rightarrow$
5		$BaCl_{2(aq)} + H_2SO_{4(aq)} \rightarrow$
6		$NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow$
7		$CuSO_{4(aq)} + Zn(NO_3)_{2(aq)} \rightarrow$
8		$Na_2CO_{3(aq)} + CaCl_{2(aq)} \rightarrow$
9		$CuSO_{4(aq)} + NH_4Cl_{(aq)} \rightarrow$
10		$NaOH_{(aq)} + AgNO_{3(aq)} \rightarrow$
11		$FeCl_{3(aq)} + NaOH_{(aq)} \rightarrow$

12		$\mathbf{CuSO_{4(aq)} + NaOH_{(aq)} \rightarrow}$

QUESTIONS AND PROBLEMS

1. For each combination described below write the equation. Include designations of state or solution in each equation. If no reaction will happen, write NR (no reaction).
   Use a solubility table as a guide to the formation of precipitates.

   a. Lead(II) nitrate and ammonium carbonate solutions are combined.

   b. Zinc chloride solution is poured into a solution of magnesium sulfate.

   c. Ammonium chloride and nickel (II) nitrate solutions are combined.

   d. Magnesium chloride solution is mixed with lithium phosphate solution.

   e. Cobalt (II) sulfate and aluminum hydroxide solutions are combined.

   f. Potassium nitrite solution is added to aluminum sulfate solution.

   g. Iron (III) chloride and sodium arsenate solutions are mixed.

   h. Sulfuric acid solution is poured into a solution of lithium carbonate.

   i. Hydrobromic acid and ammonium sulfite solutions are mixed.

   j. Calcium perchlorate solution is poured into a solution of copper (II) acetate.