10 ELECTRON CONFIGURATIONS OF ATOMS AND IONS

Small-Scale Experiment for text Sections 7.1 and 7.2

OBJECTIVES

- **Observe** colors of various chemical solutions.
- **Write** electron configurations for various metals, nonmetals, cations, and anions.
- **Relate** the presence of color in an ionic solution as a characteristic of electron configurations.

INTRODUCTION

Metals tend to have relatively low ionization energies. Thus, they generally lose electrons readily. Loss of electrons by a metal atom produces a positively charged ion called a cation. The electrical charge of a metal cation depends on the number of electrons the metal loses. When they form cations, the representative metals usually lose their valence electrons. *Valence electrons* are the electrons in the highest occupied energy level of an atom. For representative elements, the electrons in the highest occupied orbitals are in *s* and *p* sublevels. A representative element's group number on the periodic table tells you its number of valence electrons. For example, sodium in Group 1A has one valence electron. Magnesium in Group 2A has two, and aluminum (Group 3A) has three valence electrons. Thus, upon producing a cation, sodium loses one electron, magnesium loses two electrons, and aluminum loses three electrons. The formulas showing the charges of the respective cations are Na^+, Mg^{2+}, and Al^{3+}. Upon losing all its valence electrons, a representative metal cation generally has the stable outer electron configuration of a noble gas.

Nonmetals have relatively high ionization energies, so they tend not to lose electrons. Instead they gain electrons to produce negative anions. They generally gain just enough electrons to attain the stable electron configuration of a noble gas, or eight outer orbital *s* and *p* electrons. As with a metal, a nonmetal's group number indicates the number of electrons that nonmetal is likely to gain. For example, nitrogen (Group 5A) has five valence electrons and will gain three more electrons to produce the nitride ion, N^{3-}. Nitride contains a total of eight outer orbital electrons, the same as a stable noble gas. Similarly, oxygen (Group 6A) will gain two electrons to produce the oxide ion, O^{2-}, and fluorine (Group 7A) will gain one electron to produce fluoride, F^-. To write the electron configuration of any cation or anion of a representative element, write the electron configuration of the neutral atom and add or subtract the required number of electrons.

Transition metals also lose electrons to produce cations. Unlike most representative metals, the number of electrons that can be lost by transition metals can vary. Iron, for example, can form the iron(II) ion, Fe^{2+}, or the iron(III) ion, Fe^{3+}, by losing two or three electrons, respectively. In general, transition metals lose their outer *s* orbital electrons before they lose their outer *d* orbital electrons. This explains why many transition metals produce cations that carry a 2+ charge. Transition-metal ions can have higher charges by losing one or more electrons from their *d* orbitals. Transition-metal ions having partially filled *d* orbital electron configurations usually have a color. Metal cations that have no *d* electrons or completely full *d* orbitals are usually not colored.

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PURPOSE

In this experiment, you will observe a variety of chemical solutions containing common cations and anions. You will write electron configurations for many of the ions contained in the solutions. You will observe the colored solutions and draw conclusions about the electron configurations of the metal ions in the colored solutions.

SAFETY

- Wear safety goggles.
- Use small-scale pipets only for the controlled delivery of liquids.
- Don't chew gum, drink, or eat in the laboratory. Never taste a chemical in the laboratory.

MATERIALS

Small-scale pipets of the following solutions:

sodium chloride (NaCl)
magnesium sulfate ($MgSO_4$)
aluminum chloride ($AlCl_3$)
iron(III) chloride ($FeCl_3$)
calcium chloride ($CaCl_2$)
nickel(II) sulfate ($NiSO_4$)
copper(II) sulfate ($CuSO_4$)
silver nitrate ($AgNO_3$)
sodium hydroxide (NaOH)
sodium carbonate (Na_2CO_3)
sodium phosphate (Na_3PO_4)

EQUIPMENT

small-scale reaction surface

EXPERIMENTAL PAGE

1. Place one drop of each of the indicated solutions in the space provided. Record the color of each solution.

NaCl	$MgSO_4$	$AlCl_3$
$FeCl_3$	$CaCl_2$	$NiSO_4$
$CuSO_4$	$ZnCl_2$	$AgNO_3$

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2. A precipitate is a solid that separates upon mixing solutions. Predict which of the metal cations in this experiment will form colored precipitates upon the addition of NaOH. Add one drop of NaOH to find out. Record your results.

CLEANING UP

Avoid contamination by cleaning up in a way that protects you and your environment. Carefully clean the small-scale reaction surface by absorbing the contents onto a paper towel, rinse the small-scale reaction surface with a damp paper towel, and dry it. Dispose of the paper towels in the waste bin.

QUESTIONS FOR ANALYSES

Use what you learned in this experiment to answer the following questions.

1. Write the electron configurations of Na, Mg, and Al.

2. Metal ions form when metal atoms lose valence electrons—the number of electrons lost equals the ion's charge. Write the electron configurations of Na^+, Mg^{2+} and Al^{3+}. What do they all have in common?

3. Write the electron configurations of Cl and Cl^-.

4. Transition-metal ions with partially filled *d* orbitals usually have a color. Based on your observations, which solutions contain transition-metal ions with partially filled *d* orbitals?

5. Transition metals usually lose *s* orbital electrons first and then *d* electrons when they produce ions. Write electron configurations for Fe and Fe^{3+} and Ni and Ni^{2+}.

6. Copper and silver both have exceptional electron configurations because they both have full *d* orbitals at the expense of an *s* orbital. Write the electron configurations of Cu and Ag.

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7. Write the electron configurations of Cu^{2+} and Ag^{+}. Is each electron configuration consistent with the color your observed for each cation? Explain.

8. The solution Zn^{2+} ions is not colored. What does this suggest about its electron configuration? Write the electron configuration of Zn^{2+}.

9. Predict which of the following transition-metal ions has a color: Cr^{3+}, Cd^{2+}, Hg^{2+}, V^{2+}. Explain your answers.

10. Do the colored precipitates all contain transition-metal ions with partially filled *d* orbitals?

NOW IT'S YOUR TURN!

1. Predict which of the metal cations in this experiment will form colored precipitates upon the addition of Na_2CO_3. Design an experiment to find out.

2. Design and carry out an experiment to find out which metal ions form precipitates with sodium phosphate. What color are the precipitates?