ATOM INTERACTIONS

INSTRUCTIONS

(MODIFIED FOR ADEED)

Overview:

Students will observe replacement reactions. They will complete a guided experiment to test their ideas. Then, they will design their own experiment to test the reactivity of several metals in single replacement reactions. Finally, they will write balanced equations to describe the reactions they completed.

Objectives:

The student will:

- balance equations;
- describe atomic structures in terms of electrons, protons and neutrons;
- recognize the difference between atoms and ions;
- recognize the visible signs of a chemical reaction;
- organize data into tabular form;
- extract information from data tables; and
- develop a systematic approach to data collection.

Targeted Alaska Grade Level Expectations:

Science

[9-11]SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[9-11]SA1.2 The student develops an understanding of the processes of science by recognizing and analyzing multiple explanations and models, using this information to revise student's own explanation or model if necessary. (L)

[11] SB3.1 The student demonstrates an understanding of the interactions between matter and energy and the effects of these interactions on systems by predicting how an atom can interact with other atoms based on its electron configuration and verifying the results. (L)

Vocabulary:

replacement reaction - is a type of oxidation-reduction chemical reaction when an element or ion moves out of one compound and into another (one element is replaced by another in a compound); this is usually written as: A + BC AC + B ➔

ion - an atom or molecule in which the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge

electonegativity - a chemical property that describes the tendency of an atom or a functional group to attract electrons (or electron density) towards itself and thus the tendency to form negative ions

oxidation numbers - are used to keep track of how many electrons are lost or gained by each atom during electrochemical reactions; all electrochemical reactions involve the transfer of electrons; oxidation numbers keep track of which atoms are oxidized and which atoms are reduced

electron configuration - the arrangement of electrons of an atom. It concerns the way electrons can be distributed in the orbitals of the atom; electron configuration determines the chemical activity of an element

Whole Picture:

The most common application of electron configurations is in the prediction of chemical properties, in both inorganic and organic chemistry. Electron configurations describe the number and type of chemical bonds that an atom can be expected to form. There are many kinds of chemical reactions.

A single replacement reaction occurs when two different cations switch places to combine with the same anion.

In a single replacement reaction a single uncombined element replaces another in a compound. Two reactants yield two products. For example when zinc combines with hydrochloric acid, the zinc replaces hydrogen.

Replacement Reactions looks like this: A+BC=B+AC. If magnesium is dropped into a solution of Copper (II) Nitrate, the magnesium will react because it is more active (in other words wants to bond more than the copper does). If Copper is dropped into Potassium Acetate, you will find that no reaction will occur. In the activity or reactivity series, the metals with the highest propensity to donate their electrons to react are listed first, and the most unreactive metals are listed last. Therefore a metal higher on the list is able to displace anything on the list below it.

The order of activity for metals is:

Li>K>Ba>Ca>Na>Mg>Al>Mn>Zn>Cr>Fe>Co>Ni>Sn>Pb>H2>Cu>Ag>Hg>Pt>Au.

Similarly, the halogens with the highest propensity to acquire electrons are the most reactive. The activity series for halogens is F>Cl>Br>I. Due to the free state nature of A and B, all single displacement reactions are also oxidation-reduction reactions, where the key event is the movement of electrons from one reactant to another. When A and B are metals, A is always oxidized and B is always reduced. Since halogens prefer to gain electrons, A is reduced (from a 0 to –1) and B is oxidized (from –1 to 0) when A and B represent those elements.

Safety

- Eye protection must be worn at all times.
- Metal salts can be toxic; be sure students wash their hands at the end of the activity.
- 3 M HCl solution can irritate skin, spills must be washed thoroughly with water.
- Solid metals should be collected and recycled.
- Waste solutions are NOT to be poured down the sink. Wash all materials into the waste collection jars.

Materials:

- 1 Beaker, 250 mL
- Copper wire, 12 gauge (formed into a tree)
- 0.05 M $AgNO_3$, 1.7 g/200 mL
- 4 Petri dishes (a 24-well microscale test plate will also work)
- 0.5 M $CuCl_2$, 10 mL (dilute solution from Part III)
- 0.5 M $MgCl_2$, 10 mL (dilute solution from Part III)
- Magnesium, small pieces
- Copper, small pieces
- 1 Microscale testing plate, 24 - well (spot plates will also work).
- Wire or foil samples of Aluminum, Copper, Zinc, Magnesium, Iron
- Sand paper or steel wool for polishing metal samples
- 5 Thin-stem pipets (or dropper bottles) filled with the following solutions:
- 1 M Aluminum chloride, 121 g AlCl3.6H2O per 500 mL solution
- 1 M Copper(II) chloride, 85 g CuCl2.2H2O per 500 mL solution
- 1 M Zinc chloride, 68 g $ZnCl_2$ per 500 mL solution
- 1 M Magnesium chloride, 102 g MgCl2.6H2O per 500 mL solution
- 1 M Iron (III) chloride, 135 g FeCl3.6H2O per 500 mL solution (Iron(II) chloride will not work.)

All students should have individual sets of materials for observations if possible. They can work in groups of two or three for brainstorming.

Activity Procedure:

Gear-up

Process Skills: observing, making quantitative and qualitative observations, analyzing data

1. The teacher will demonstrate the reaction between copper metal, and silver nitrate solution, $AgNO_3$(aq).

2. Students should record their observations at these time intervals: start, two minutes, ten minutes, and next day.
3. The teacher will ask the students orally what they know about the vocabulary: electron configuration, replacement reactions, ions, electronegativity and oxidation numbers or will ask questions to get at their understanding of the vocabulary. Questions will be answered in their science journal.

Copper metal/silver nitrate Replacement Reaction Pre-Lab Discussion

4. This laboratory activity opens with a teacher demonstration designed to help students develop the notions that ions and atoms have different physical and chemical properties and that ions can be transformed into atoms and atoms can become ions.
5. Demonstration: Bend the copper wire into a tree-like shape small enough to be completely covered by the silver nitrate solution. Allow this system to stand undisturbed until the next day. Use a heavy gauge wire so there will still be enough copper to support the shape of the tree. The dramatic change in physical properties of the solids and solutions while the silver crystallizes, helps emphasize that silver ions (Ag^+) have become silver atoms (Ag) while copper atoms (Cu) have become copper ions (Cu^+). At the end of the first day, the teacher will question again, the students orally to get at what they know about the vocabulary words: electron configuration, replacement reaction, ions, electronegativity, and oxidation numbers.
6. Gear-up Questions (students will write their answers in their science journal)
   a) List all the evidence suggesting that a chemical reaction occurred when copper metal was placed in the silver nitrate solution.
   b) What is the difference between the number of silver ions remaining in the solution at the end of one day and the number of silver ions present in the solution initially?
   c) How are the physical properties of silver ions different from those of the silver atoms produced?
   d) What change in the number of electrons occurred as one silver ion, Ag+, became a silver atom, Ag?
   e) Which metal ion could be responsible for the solution color observed at the end of the copper and silver nitrate demonstration? What was the source of these ions?

Explore

Process Skills: observing, making quantitative observations, measuring, analyzing data

7. Explore Activity: Comparing the Activity of Two Metals
   a) Students will rank the activity of metals by comparing their behavior in the presence of the ions of other metals.
   b) Certain metals are more chemically active than others. You can rank the reactivity of metals by comparing their behavior in the presence of the ions of other metals.
8. Hand out student activity guide.
   a) Clean all solid metal samples with steel wool.
   b) Pour 10 mL of 0.5 M copper(II) chloride solution, $CuCl_2$(aq), into each of two petri dishes.
   c) Drop a small piece of magnesium metal, Mg(s), into the solution in one dish and a small piece of copper metal, Cu(s), into the second dish.
   d) Pour 10 mL of 0.5 M magnesium chloride solution, $MgCl_2$(aq), into two other petri dishes.

	Mg	Cu
Mg^{2+}		
Cu^{2+}		

   e) Drop a small piece of magnesium metal, Mg(s), into the one petri dish containing $MgCl_2$ solution and a small piece of copper, Cu(s), into the other dish.
   f) Observe, describe, and record what occurs in each petri dish in a data table larger than the one above.
9. Be sure that students think through the need to compare the metal (atoms) with both of the solutions (metal ions). This reaction may form hydrogen gas, and should be noted, but students should not include hydrogen in their rankings at this time.

Generalize

Process Skills: interpreting, generalizing, describing, analyzing data

10. Students will compare class data from the Explore Activity and will answer the questions orally as a class discussion to assess what they have learned.
    a) 1. Does Cu metal react with Cu^{2+} solution?
    b) Does Mg metal react with Cu^{2+} solution?
    c) Does Mg metal react with Mg^{2+} solution?
    d) Which metal (Cu or Mg) is more active? Justify your answer.
    e) Discuss as a class the replacement reaction that occurred.
    f) How did the number of electrons present in each magnesium atom change as this reaction occurred?
    g) How did the number of electrons present in each copper(II) ion change as this reaction occurred?
    h) What do chemists mean when they say a "replacement reaction" occurred?
    i) Look at a periodic table and find copper and magnesium.
    j) How does their placement on the periodic table correspond with their electron configuration and relative chemical activity?
    k) How will they compare to other metals in the same column (group or family)?
    l) How will they compare to other metals in the same row (period or energy level or electron configuation)? Let's find out using an experiment!

Experiment

Process Skills: predicting, observing, measuring, making quantitative observations, controlling experimental variables

11. Experiment Activity: Designing Your Own Experiment (Hand out page two of the Student Guide)
    a) Students will be given solutions containing the ions aluminum, Al^{3+}; magnesium, Mg^{2+}; iron(III), Fe^{3+}; copper(II), Cu^{2+}; and zinc, Zn^{2+}; and the corresponding metals aluminum Al; magnesium, Mg; iron, Fe; copper, Cu; and zinc, Zn.
    b) Create and complete a procedure that will enable you to determine and rank the assigned metals in terms of their ability to replace other ions in solution. Predict the activity of each metal by making a list of the metals, starting with the most active. Create a data table and record what occurs in each case.
    c) Rank the activity of these metals; Al, Cu, Fe, Mg, and Zn. Start the list with the most active metal.
    d) Wash hands thoroughly before leaving the laboratory.
12. Work with students in small groups to help them devise the experimental procedures and make the data table (see answer section for table design). Students should be sure they have checked all possible combinations.

Interpret

Process Skills: analyzing data, interpreting, developing models, drawing

Conclusions

13. The students will do the following written activities.
    a) For the copper wire and silver nitrate reaction in the Gear-up Activity Teacher Demo students will draw a set of diagrams to show what happens to the individual atoms or ions as the reaction proceeds (pretend it is possible to see individual atoms and ions). Create your own symbols to represent the individual units. Be sure to label all parts of your drawings.
    b) Using correct symbols, write balanced equations for the reactions between the following materials. Assume that iron forms iron(III) ions in solution. If no observable reaction occurs write no reaction.
        I. zinc metal and copper(II) chloride
        II. iron metal and copper(II) chloride
        III. magnesium metal and zinc chloride
        IV. aluminum metal and iron(III) chloride
        V. iron metal and aluminum chloride
        VI. copper metal and zinc chloride

c) Students will write their data in a class data table to compare with other groups.
d) Students will then find each of the metals on the periodic table and will explain in their science journal the correlation of the relationship of the metal's placement on the periodic table with its electron configuration and relative chemical activity.

Apply/Assess:
Process Skills: applying conclusions to other problems

14. Dipping iron nails into molten zinc results in galvanized nails. Why are such nails manufactured?
15. Individuals living near copper mines sometimes earn extra money by leaving iron objects suspended in the waste waters flowing from the mine area. What is their "secret"?
16. Complete the assessment activity found after "Anticipated Student Results."

Extension Ideas:

1. Industrial methods of metal recovery and smelting.
2. Importance of corrosion control.
3. Societal issues of energy demands to produce new metals versus recycling of metals.

Resources

http://wiki.answers.com/Q/What_is_single_replacement
http://dwb.unl.edu/Chemistry/LABS/LABS08.html
http://en.wikipedia.org/wiki/Single_displacement_reaction

Anticipated Answers:

Gear-Up Activity

Start: Answers will vary
Two minutes: Black surface forming on wire; blue color appearing near the wire.
Ten minutes: Black/silver gray surface on wire; distinct blue color appearing.
Next day: Long moss-like crystals, silver gray to black color crystals, intense blue color to solution.

Explore Activity

	Mg	Cu
Mg^{2+}	No	No
Cu^{2+}	Yes	No

Experiment Activity

	Mg	Zn	Al	Fe	Cu
$MgCl_2$	No	No	No	No	No
$CuCl_2$	Yes	Yes	Yes	Yes	No
$FeCl_3$	Yes	Yes	Yes	No	No
$AlCl_3$	Yes	Yes	No	No	No
$ZnCl_2$	Yes	No	No	No	No

Note: these two metals are adjacent in the activity series. Many students may not observe this replacement since it is very slow.

Answers to Data Analysis

Gear-up Activity (answered in science journal)

1. Answers will vary but should include that a solid (metallic silver) is formed and that a color change occurs (appearance of the blue copper(II) nitrate solution).
2. There is less silver (technically, silver ions) after 24 hours. The discussion should be linked to the idea of conservation of matter since the silver that appeared had to come from somewhere.
3. Answers will vary but should include that silver ions are soluble in solution but silver atoms are not soluble; silver ions are colorless but silver atoms have a metallic luster.
4. The number of electrons increased. Silver ions have acquired electrons from the copper atoms and thus become silver atoms while copper atoms become copper ions.
5. The copper wire (atoms) is the source of the copper ions that cause the blue color.

Explore Activity/Generalize Questions (answered orally)

1. No.
2. Yes, magnesium atoms are converted to magnesium ions while copper ions become copper atoms and plate onto the magnesium.
3. No.
4. Magnesium. Answers should include the generation of a gas and the plating of metallic copper onto the magnesium.
5. The magnesium formed magnesium ions and replaced copper ions in solution as copper ions formed copper atoms.
6. The magnesium lost electrons. Magnesium atoms have given electrons to the copper ions resulting in the formation of copper atoms.
7. The copper gained electrons. Magnesium atoms have given electrons to the copper ions resulting in the formation of copper atoms.
8. Answers will vary but should attempt to identify that the metals changed in some manner with metal ions in solution taking the place of the solid metal while solid metal atoms became ions in solution. Technically, these reactions involve a transfer of electrons from the more active metal to the less active partner. Do not attempt to introduce oxidation-reduction at this time; rather seek the notion that the appearance of one metal occurs at the expense of the other metal.

Experiment Activity (answered in science journal)

1. Answers will vary. The main reason is to remove any coatings and expose pure metal.
2. a) No apparent reaction.
   b) Answer will vary, but zinc metal does react with the iron(III) solution.
   c) Answers will vary, but the formation of the copper plate on the iron is most apparent.
3. Al, Zn, Mg, Fe
4. Zn, Al
5. Mg, Al, Zn, Fe, Cu (Evaluation of student answers depends upon student data.)

Answers to Interpret and Apply (answered in science journal)

1. answers vary
2. a) Zinc and copper(II) chloride
   $Zn(s) + CuCl_2(aq) \text{ --> } Cu(s) + ZnCl_2(aq)$
   b) Iron and copper(II) chloride
   $2\ Fe(s) + 3\ CuCl_2(aq) \text{ --> } 3\ Cu(s) + 2\ FeCl_3(aq)$
   c) Magnesium and zinc chloride
   $Mg(s) + ZnCl_2(aq) \text{ --> } Zn(s) + MgCl_2(aq)$
   d) Aluminum and iron(III) chloride
   $Al(s) + FeCl_3(aq) \text{ --> } Fe(s) + AlCl_3(aq)$
   e) Iron and aluminum chloride

$Fe(s) + AlCl_3(aq)$ --> No reaction
f) Copper and zinc chloride
$Cu(s) + ZnCl_2(aq)$ --> No reaction

3. This item evaluates students' abilities to link the replacement reaction observed with protection of metals. The coating of zinc prolongs the useful life of the iron nail by corroding before the iron.
4. The iron will replace the copper ions, producing metallic copper and iron ions. Assuming the recovered copper metal is more valuable than the original iron, monetary gain is possible!

Assessing the Laboratory Learning (choose one of the following activities: Laboratory Practical or Written Exercises)

Laboratory Practical

Give students samples of three different metals labeled J, K, and L along with three thin-stem pipets containing chloride salts of the three metals. Use J for copper and copper(II) chloride, L for aluminum and aluminum chloride, and K for magnesium and magnesium chloride. Give student the following instructions:

a) Design a procedure to confirm, using the minimum number of tests, the proposed activity series shown below.
   K --most active
   L
   J -- least active

b) Conduct your proposed procedure.

Written Exercises

Give students the following activity sheet (provided as a STUDENT WORKSHEET at the end of this lesson).

Given samples of metals J, K, and L along with solutions of their chloride salts.

1. What is the minimum number of tests necessary to confirm the proposed activity series listed below?
   K -- most active
   L
   J -- least active
2. Describe the sequence of procedures you would use to confirm this activity series.

Here is a copy of a portion of a data table:

	Cl solution	Br-solution	I-solution	Zn metal
Br_2	No	Yes	No	No
Cl_2	No	Yes	Yes	Yes
I_2	No	No	No	Yes
Zn^{2+}	No	No	No	No

3. Using the data provided this table, rank all the halogens listed, from the most active to the least active.
4. Using the data provided, which ion is most likely to lose electrons? Explain your answer.
5. Write a balanced equation for each reaction that occurred.

Answers to Student Assessment

Laboratory Practical: Refer to the answer for assessment item

B. Assign credit in accordance with the logic behind the students' answers in addition to their correctness.

Answers to Written Exercises:

1. Three
2. Answers will vary. One suggested method is to test K against L chloride, to test K against J chloride, and to test L against J chloride.
3. Cl_2 (most active), Br_2, I_2 (least active)

4. I-, since it reacted with both Cl_2 and Br_2. Zn metal is readily oxidized to Zn^{2+} but as an ion is unable to lose any more electrons.
5. Cl_2(aq) + 2 NaBr(aq) --> Br_2(aq) + 2 NaCl(aq)
   Cl_2(aq) + 2 NaI(aq) --> I_2(aq) + 2 NaCl(aq)
   Br_2(aq) + 2 NaI(aq) --> I_2(aq) + 2 NaBr(aq)
   Cl_2(g) + Zn(s) --> $ZnCl_2$(s)
   Br_2(aq) + Zn(s) --> $ZnBr_2$(s)
   I_2(aq) + Zn(s) --> ZnI_2(s)

ATOM INTERACTIONS

Rubric:

Objectives	Emerging	Developing	Proficient	Advanced	Earned Points
Experimental Design	**0 points** Missing three or more parts or three or more parts incomplete from the "advanced" criteria.	**1 point** Missing two parts or two parts incomplete from the "advanced" criteria.	**2 points** Missing one part or one part incomplete from the "advanced" criteria.	**3 points** Procedure described is logical and sequential. All metals are included in the experiment. Data table neat, complete and labeled correctly. Variables controlled and defined. Prediction of activity of each metal is made.	
Lab performance: Accuracy of results for the Gear-up, Explore and Experiment Activities	0 points Lab activities 69% or less completed or 69% or less accurate	1 point Lab activities 70-79% completed or 70-79% accurate	2 points All lab activities completed and 80-89% accurate	3 points All lab activities completed and 90-100% accurate	
Lab safety	0 points Reminded student more than once to put safety goggles on	1 point Reminded student once to put on safety goggles and lab procedures sloppy, spills and equipment not cleaned	2 points Remind student once to put on safety goggles or lab procedures sloppy, spills and equipment not cleaned	3 points Students wear safety goggles throughout the lab and lab procedures neat and precise, spills and equipment cleaned.	
Science journal	0 points Questions 69% or less completed or 69% or less accurate	1 point Questions70- 79% completed or 70-79% accurate	2 points Questions completed and 80- 89% accurate	3 points Questions completed and 90-100% accurate	
Assessment: Lab Practical*	0 points Missing two or more parts or two or more parts incomplete from the "advanced" criteria and the results are below 69% accurate.	1 point Missing one or more parts or one or more parts incomplete from the "advanced" criteria and the results are 70-79% accurate.	2 points Missing one part or one part incomplete from the "advanced" criteria and results of experiment 80-89% accurate.	3 points Procedure described is logical and sequential. All metals are included in the experiment. Data table neat, complete and labeled correctly. Variables controlled and defined. Prediction of activity of each metal is made. Results of the experiment are 90-100% accurate.	
Assessment: Written Exercises*	0 points Questions 69% or less completed or 69% or less accurate	1 point Questions70- 79% completed or 70-79% accurate	2 points Questions completed and 80-89% accurate	3 points Questions completed and 90-100% accurate	
*choose one				Score:	

NAME: ______________________________ STUDENT WORKSHEET

ATOM INTERACTIONS

General Safety Considerations

Wear protective glasses and an apron at all times. Avoid skin contact with solids and solutions. Dispose of all solutions and solid metal samples in the containers provided by your teacher. Wash your hands before leaving the laboratory.

Comparing the Activity of Two Metals

Certain metals are more chemically active than others. You can rank the reactivity of metals by comparing their behavior in the presence of the ions of other metals.

1. Clean all solid metal samples with steel wool.

2. Pour 10 mL of 0.5 M copper(II) chloride solution, $CuCl_2(aq)$, into each of two petri dishes.

3. Drop a small piece of magnesium metal, Mg(s), into the solution in one dish and a small piece of copper metal, Cu(s), into the second dish.

4. Pour 10 mL of 0.5 M magnesium chloride solution, $MgCl_2(aq)$, into two other petri dishes.

	Mg	Cu
Mg^{2+}	No	No
Cu^{2+}	Yes	No

5. Drop a small piece of magnesium metal, Mg(s), into the one petri dish containing $MgCl_2$ solution and a small piece of copper, Cu(s), into the other dish.

6. Observe, describe, and record what occurs in each petri dish in a data table larger than the one above.

Designing Your Own Experiment

You will be given solutions containing the ions aluminum, Al^{3+}; magnesium, Mg^{2+}; iron(III), Fe^{3+}; copper(II), Cu^{2+}; and zinc, Zn^{2+}; and the corresponding metals aluminum Al; magnesium, Mg; iron, Fe; copper, Cu; and zinc, Zn.

1. Create and complete a procedure that will enable you to determine and rank the assigned metals in terms of their ability to replace other ions in solution. Predict the activity of each metal by making a list of the metals, starting with the most active. Create a data table and record what occurs in each case.
2. Rank the activity of these metals; Al, Cu, Fe, Mg, and Zn. Start the list with the most active metal.
3. Wash hands thoroughly before leaving the laboratory.

NAME: ______________________________

STUDENT WORKSHEET

WRITTEN EXERCISES

Directions: Answer the following questions.

Given samples of metals J, K, and L along with solutions of their chloride salts:

1. What is the minimum number of tests necessary to confirm the proposed activity series listed below?

   K -- most active

   L

   J -- least active

   Your answer: _____________

2. Describe the sequence of procedures you would use to confirm this activity series.

   ____

   ____

   ____

   ____

Here is a copy of a portion of a data table:

	Cl solution	Br-solution	I-solution	Zn metal
Br_2	No	Yes	No	No
Cl_2	No	Yes	Yes	Yes
I_2	No	No	No	Yes
Zn^{2+}	No	No	No	No

3. Using the data provided this table, rank all the halogens listed, from the most active to the least active.

   ____

4. Using the data provided, which ion is most likely to lose electrons? Explain your answer.

   ____

   ____

   ____

5. Write a balanced equation for each reaction that occurred.

   ____

   ____

   ____

   ____