Section 5.3 Reactions and Environmental Issues

(Student textbook pages 199 to 206)

In this section, students examine the application of chemical solutions to chemical pollution concerns.

Common Misconceptions

- Chemicals are often thought of as either beneficial or harmful. The phosphate in Activity 5-4 illustrates that chemicals may be both helpful (removing copper contamination) and harmful (causing algae blooms).

Background Knowledge

When discussing toxic materials, it may be helpful to distinguish between the fat-soluble and water-soluble nature of the chemicals. Discuss that fat-soluble toxins accumulate in the body as they are stored in body fat. Reactivate prior learning about bioaccumulation, pointing out that, though environmental levels of toxins may be low, these toxins can build up to high levels in the body, resulting in symptoms.

In contrast, water-soluble toxins are excreted in the urine, so don't accumulate in the body. This links the risk of side effects directly to the concentration of water-soluble toxins in the environment.

Literacy Support

Using the Text

- Ask students to recall from previous studies (e.g., grade 9 ecology) what they know about toxic spills and clean-up. Let students know that it takes years after a spill to fully determine the environmental impact it had. Discuss natural disasters such as Hurricane Katrina (2005) and the 2004 Tsunami in Southeast Asia, focussing on the secondary disasters in terms of chemical and oil spills from damaged factories and refineries. Although residents may be able to return to their homes, sometimes the clean-up of contamination continues for years.

Before Reading

- Split the class into groups of three. Ask students to record on chart paper what they know about toxic materials and environmental issues. (Many students have studied this in geography and previous science units.)

During Reading

- Have students read the text in small groups in which each person has a task: a reader, a presenter, and a recorder (who summarizes what is read).

After Reading

- Group members discuss the notes then each add pieces of information. Presenters then move to a new group, sharing their notes with them. Presenters should move to a third group and repeat, if there is time.

Using the Images

- The photo shows an ecosystem in peril. Ask students to examine the photo and predict what they think has happened in this ecosystem, what the problem is, how it occurred, and what is being done to solve the problem.
- Have small groups of students brainstorm at least three problems that result from the spill: environmental, economical, and social.
- Survey the class for information about other spills of local or national/international significance (e.g., the 1989 Exxon Valdez oil spill or the 1979 Mississauga train derailment, which spilled propane, chlorine, and styrene).

Specific Expectations

- **C1.1** assess the usefulness of and/or the hazards associated with common elements or compounds in terms of their physical and chemical properties
- **C1.2** assess social, environmental, and economic impacts of the use of common elements or compounds

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check question 1, page 201	Decomposition reactions are recognized as removing the hazard.	Review the images in the textbook and discuss the different ways that oil may be cleaned up.
Activity 5-4 "Taking Care" of Toxic Metals questions 2–3, page 200	Students recognize that the phosphate that remains in the water after the copper is removed causes its own concerns.	Review solubility charts to show that phosphates are soluble and will dissolve in water. Remind students that overuse of fertilizers (which contain phosphate) causes increased plant growth in our lakes due to run-off.

Instructional Strategies

- Have students read the section individually, then discuss the issues presented.
- Use a jigsaw approach for this section. Divide the class into three "expert" groups. Each group should prepare a summary of the issue in the form of a consumer report. Then, form new groups in which an expert from each area presents their group's report. Summaries should analyze uses, hazards, disposal concerns, green alternatives, and cost to consumer and the environment. Copies may be retained by each student as a study tool. You may wish to use **BLM A-22 Project Group Assessment Checklist** to assess this activity.
- To conclude, each student should choose one topic and write a letter to the head of research at a manufacturer. The letter must be formal and discuss the physical and chemical properties and changes of the toxic materials in use and suggest a green alternative in a convincing argument for its use.
- Have students carry out Activity 5-4 "Taking Care" of Toxic Materials. See page TR-2-48 of this Teacher's Resource for teaching notes on this lab.
- Read the Making a Difference feature as a class. See page TR-2-4 of this Teacher's Resource for notes on using this feature.

Activity 5-4 "Taking Care" of Toxic Materials (Student textbook page 200)

Pedagogical Purpose

This activity demonstrates a chemical solution to the environmental problem of contaminated drinking water. A chemical reaction is used to form a precipitate containing the toxin, which can then be filtered out.

Planning		
Materials	110 mL 0.02 mol/L copper(II) chloride solution 20 mL saturated sodium phosphate solution 100 mL graduated cylinder **BLM 5-10 "Taking Care" of Toxic Materials** Two days before, prepare solutions and place in dropping bottles.	2 droppers or dropper bottles Two 250 mL beakers Coloured pencils (optional)
Time	20 min	
Safety	Safety goggles and aprons should be worn.	

Background

In this investigation, copper ions are used to model toxic lead. Lead ions would similarly form a precipitate. Lead compounds are not used in this investigation because of the many health concerns associated with their handling and disposal. Lead is a fat-soluble ion that is pervasive because of bioaccumulation and because it does not break down.

Notice that both reactants are aqueous, and mixing results in a double displacement reaction which produces soluble sodium chloride ions and a blue precipitate of copper(II) phosphate.

$CuCl_2(aq) + Na_3PO_4(aq) \rightarrow NaCl(aq) + Cu_3(PO_4)_2(s)$

Note that using chemicals to clean up other chemicals creates often leaves excess clean-up chemicals behind, not a pure environment.

Activity Notes and Troubleshooting

- Begin with a discussion of copper imbalances in the body and how this is linked to health problems such as anorexia, fatigue, and depression. Excess copper usually enters the body through drinking water as copper is displaced from plumbing, cookware, or the environment.
- Refer students to the Science Skills Toolkit 4 on page 538 of the student textbook to reactivate understanding of the proper use of a graduated cylinder.
- Set out materials at stations around the class to reduce congestion.

Additional Support

- ELL Encourage students to draw their observations using coloured pencils.
- Hand out copies of **BLM 5-10 "Taking Care" of Toxic Materials,** which provides scaffolding for observations and analysis.

Answers

1. copper
2. chloride ions
3. While the phosphate in sodium phosphate helps clean the copper out of drinking water, it may cause a different problem as described.

Learning Check Answers (Student textbook page 201)

1. They can help break down the oil.
2. nitrogen oxides and gasoline
3. It provides more access to the catalyst.
4. to maximize the volume of pollutants converted

Learning Check Answers (Student textbook page 204)

5. because it is effective and less costly
6. Example:

Positive effects	Negative effects
gold separated	cyanide contaminates environment zinc becomes contaminated large amounts of energy required

7. chlorine
8. They may burn skin or react explosively.

Section 5.3 Review Answers (Student textbook page 206)

Please see also **BLM 5-11 Section 5.3 Review (Alternative Format).**

1. Decomposition reactions help break up the oil.
2. It is impractical to provide a tank of pure oxygen gas for the reaction. Nitrogen is allowed in the reaction chamber only because it makes up most of the air in the atmosphere.

3. Example: Negative results include replacement cost and increased insurance cost as well as increased toxic emissions. Sport utility vehicles are most often the target because they have greater ground clearance, making it easier to access. Possible solutions include making it less accessible or harder to remove and attaching an alarm, or using a less valuable catalyst.
4. Example: air pollution from motor exhaust, contaminated leachate from gold processing, and excess phosphate from fertilizers
5. The substance is corrosive.

6. Catalysts are placed on the surface of the honeycomb structure in the catalytic converter, to maximize the amount (surface area) available to speed the reaction.
7. chloramines, chlorine
8. Answers will vary depending on the product chosen. Students could create a brochure, a graphic novel, a podcast, a commercial, a slide/multimedia presentation, or design and build actual packaging for the new product. They should include a new logo, identify the benefits, list the ingredients, and emphasize the reduced packaging and the nature of the packaging. Some green products to consider are body-care and cosmetics, textiles and flooring alternatives, or products used in the home, such as laundry detergents, fabric softeners, bleaches, and cleaning products (e.g., vinegar, pure soap, baking soda, borax, washing soda, drain, toilet bowl, and rug cleaners).

   Students should select products containing a majority of organic ingredients, products not tested on animals, products that use minimal packaging, and ideally packaging that is reusable, recyclable, or biodegradable.

Plan Your Own Investigation 5-A Evidence of Chemical Change (Student textbook page 207)

Pedagogical Purpose

Students design and carry out an investigation with the purpose of observing as many signs of chemical change as possible. They gain experience in experimental design, as well as interpreting MSDS to identify safety precautions and prevent dangerous reactions.

Planning		
Materials	MSDS for each material Copper(II) carbonate solution Dilute sulfuric acid Saturated calcium hydroxide solution Test tubes Tongs **BLM 5-3 Evidence of Chemical Change** A week before, prepare solutions and make copies of the BLM and MSDS for each material.	Ammonium carbonate solution Magnesium ribbon Universal indicator solution Scoopula Test-tube rack Utility knife (optional)
Time	60 min	
Safety	Wear safety goggles, gloves, and a lab apron. Sulfuric acid can injure eyes and sensitive skin. Avoid contact. Do not touch materials with bare fingers. Use tongs or forceps. Clean up all spills immediately.	

Background

Matter is never destroyed or created in chemical reactions—when a chemical change occurs, atoms are simply rearranged.

A chemical change is a change in which something new is formed. Chemical change results in one or more substances of entirely different composition from the original substances. The elements and/or compounds at the start of the reaction are rearranged into new product compounds or elements. During a chemical change, chemical bonds between atoms are broken and new chemical bonds formed. This results in a rearrangement of the chemical bonds.

There are several different types of chemical change reactions. These include synthesis, decomposition, single displacement, double displacement, neutralization, and oxidation/reduction reactions.

The following explains some of the reactions to be expected:

- In some reactions the carbonic acid will decompose to form carbon dioxide gas which can be tested for using the flame test (it will be extinguished).
- Before performing this investigation, review the method with students and provide feedback as many students will not think to record temperature changes.
- Students should prepare an observation table that includes qualitative observations for before, during, and after the reaction has occurred. Students will perform each step of the procedure and, to identify a chemical change, should look for observable signs such as colour change, precipitate formation, energy changes (heat or light) and/or formation of a gas as clues to chemical change. You may wish to have students use **BLM G-12 Creating Data Tables** for this activity.
- Universal indicator is listed in the materials as it can be used to indicate a range of pH from red in a strong acid (pH 0–3), orange/yellow (pH 3–6), green (pH 7), blue (pH 8–11) to purple (pH 11–14). The pH observations should be included in the observations chart.

- Enrichment—Ask students to provide the balanced chemical equation for each reaction and list the type of reaction that occurred as a Chapter 5 summary.
- In the copper reactions, students might notice a change in the blue Cu^{2+} ions to green Cu^{1+} ions due to an oxidation-reduction reaction in which electrons are gained by the Cu^{2+}.
- Temperature change might be noticeable when sulphuric acid and magnesium are mixed.
- Calcium carbonate forms an insoluble white precipitate when formed in solution.
- Ammonia has a distinctive, pungent smell and disperses easily, since it is lighter than air.
- Copper(II) hydroxide forms as a jelly-like blue precipitate.
- Hydrogen gas is produced when an acid and magnesium react, confirmed by the loud "popping" noise resulting from a flaming splint test.

Activity Notes and Troubleshooting

- Verify designs have appropriate safety precautions and waste disposal instructions before allowing students to carry out their procedures.
- Limit investigations to 10 combinations of chemicals.
- Procedures should use small quantities of solutions (3 to 5 mL each).
- Ensure materials include necessary and appropriate equipment such as large test tubes to trap gases for a flame test.
- Students may wish to use a flame test or glowing splint test to check if or what kind of gas was produced.
- Direct students to use only three drops of indicator.
- Provide magnesium strips, instructing students to use just 2 cm lengths.
- Have students list, at the top of their observation sheet, the six signs of chemical change, and limit their observations to these (without inferring, for example, which gas is produced).
- To assess this activity, you may wish to use **BLM A-1 Making Observations and Inferences Checklist.**

Additional Support

- ELL Permit students to use a procedural flow chart rather than traditional narrative steps.
- Provide a sample of steps for a single reaction to help students get started.

Inquiry Investigation 5-B Synthesis and Decomposition Reactions (Student textbook pages 208 to 209)

Pedagogical Purpose

This activity shows students the result of decomposition and synthesis reactions. Students follow procedural design and analyze results.

Planning	
Materials	3 × 3 cm steel wool 60 mL 3% hydrogen peroxide solution Pinch of yeast Tongs 250 mL beaker Insulated gauze pad Striker **BLM 5-5 Synthesis and Decomposition Reactions** One day before, prepare samples of materials and copies of the BLM.
Time	30 min
Safety	Wear safety goggles and a lab apron. Burning iron becomes very hot. Be sure to wear thermal gloves.

Background

Hydrogen peroxide is not a very stable compound. Under normal conditions it slowly decomposes to water and oxygen. Exposure to light speeds up this process, so it is sold and stored in dark brown opaque bottles to prevent decomposition into water and oxygen. Yeast contains catalase enzymes that speed up the decomposition. The oxygen that is produced then supports combustion and the steel wool (iron) will glow bright red in the excess oxygen.

$$2HOOH \rightarrow 2H_2O + O_2$$

Activity Notes and Troubleshooting

- Provide students with the formula for hydrogen peroxide (H_2O_2), and show them a model as you point out the similarities and differences to water. Ask students to predict its reactivity based on its structure.
- Discuss catalysts with students and provide examples such as the catalytic converter in a car, and amylase and catalase enzymes that speed up digestion.
- Demonstrate how to create sparks with the striker.
- Remind students of amounts of chemicals to be used and model how much a "pinch" of yeast is.
- Ensure students understand that the insulated gauze pad (or cotton) must stay in place to prevent gas from escaping the beaker. In step 3, the pad should be moved aside just enough to get the steel wool inside.
- Caution students not to let the steel touch the liquid, as this will extinguish it.

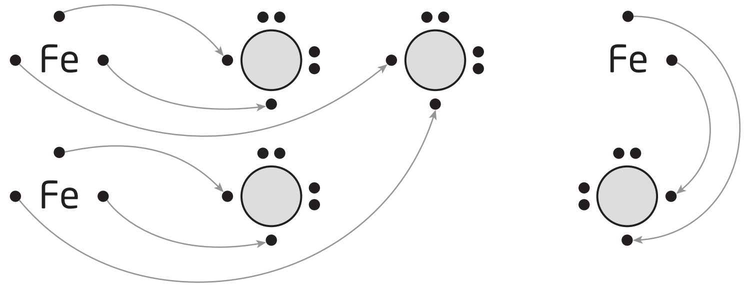
Additional Support

- Have students do a placemat activity to recall the types of reactions. The four corners are labelled: double displacement, single displacement, synthesis, and decomposition. For each one, have them write or illustrate a definition, general formula, and an example.

Answers

1. A catalyst is a material that speeds up a reaction. The yeast was used so that the reaction would happen fast enough to perform the investigation.
2. $Fe + O_2(g)$

3. Example:



The iron loses electrons to the oxygen forming an ionic bond.

4. The yeast is a catalyst that speeds the decomposition of hydrogen peroxide into water and oxygen $2H_2O_2 \xrightarrow{\text{yeast}} 2H_2O(\ell) + O_2(g)$. Drawings should show the hydrogen peroxide molecule breaking apart into pairs of hydrogen atoms and oxygen atoms.

5. iron (steel wool) + oxygen → iron oxide
$3Fe + 2O_2 \rightarrow Fe_3O_4$

Diagrams should show three atoms of iron sharing electrons with two groups of two oxygen atoms to form molecules of three iron atoms and four oxygen atoms.

6. Example: What other chemicals cause the rusting or oxidation of steel wool, or if other signs of reaction are present? For example, see how rapidly vinegar rusts the steel wool, or if heat is released.

7. Example: Cosmetics containing iron oxides have been used for hundreds of years. These cosmetics use various forms of iron oxides because they are fine powders that have varying pigments in the yellow, red, and black families, specifically reddish brown, light brown, and sandy colours.

Inquiry Investigation 5-C Displacement Reactions

(Student textbook pages 210 to 211)

Pedagogical Purpose

Students will examine single and double displacements by reacting metals with salt solutions and salt solutions with other salt solutions. They will make accurate observations to determine what type of displacement reaction has occurred.

Planning		
Materials	3 test tubes 15 cm magnesium ribbon Calcium chloride 30 mL warm water **BLM 5-8 Displacement Reactions** One or two days before, gather materials and make copies of the BLM.	3 rubber stoppers Fine copper(II) sulfate crystals Sodium carbonate Pencil
Time	45 min	
Safety	Wear safety goggles, gloves, and a lab apron. Avoid skin contact with copper(II) sulfate dust and solution. Keep your work area clean. Wipe up any spills and inform your teacher immediately.	

Background

Many chemical changes happen when you bring together two or more different substances. When two or more substances form new substances, it is called a chemical reaction. There are so many chemical reactions that it is helpful to classify them into six general types: synthesis, decomposition, single displacement, double displacement, neutralization, and oxidation/reduction.

Recall that using the activity series, Cu can replace Ag in a chemical reaction because Cu is more reactive than Ag. Thus, a more reactive element can displace a less reactive element from a compound.

In this investigation, students will mix metals with salt solutions and determine if a chemical change occurs. Solubility of the precipitate formed is determined by the solubility rules guidelines.

Activity Notes and Troubleshooting

- Demonstrate how to gently shake the test tubes.
- Ensure students understand that they must remove the pencil once the magnesium is coiled. Do not place the pencil in the solution.
- Explain proper disposal procedures.
- Remind students to use the series to make predictions prior to performing the lab to determine whether one element can displace another element in a compound.
- Have students use their observations to determine if the reactions are single or double displacement and to record the names of the products formed. You may wish to have students use **BLM 5-8 Displacement Reactions** for this activity.

Additional Support

- Use models on board to illustrate the single and double displacement reactions.
- Provide a particle diagram (such as a Lewis-dot diagram) as a model for students.

Answers

1. Test tube A: copper Cu^{2+} and sulfate SO_4^{2-}:$[Cu]^{2+}$ $[SO_4]^{2-}$
   Test tube B: calcium Ca^{2+} and chlorine Cl^-:$[Ca]^{2+}$ $[Cl]^-$ $[Cl]^-$
   Test tube C: sodium Na^+ and carbonate CO_3^{2-}:$[Na]^+$ $[Na]^+$ $[CO_3]^{2-}$

2.

Test Tube	Reactants	Products	Reaction Type
A	copper(II) sulfate and magnesium	magnesium sulfate and copper	single displacement
B	magnesium sulfate and calcium chloride	magnesium chloride and calcium sulfate	double displacement
C	magnesium sulfate and sodium carbonate	magnesium carbonate and sodium sulfate	double displacement

3. See the Products column in the table above. Example explanations: A: The blue colour disappeared and a reddish solid (copper) appeared. The silvery magnesium metal dissolved into solution, so the second product was soluble magnesium sulfate, which is a salt that easily dissolves in solution; B: The ions from the two substances switched partners to form soluble magnesium chloride and a white precipitate of calcium; C: The icons from the two substances switched partners to form the new substances insoluble magnesium carbonate and soluble sodium sulfate.

4. See the Reaction Type column in the table above.

5. A: copper(II) sulfate + magnesium → magnesium sulfate + copper;
   B: magnesium sulfate + calcium chloride → magnesium chloride + calcium sulfate;
   C: magnesium sulfate + sodium carbonate → magnesium carbonate + sodium sulfate

6. A: $CuSO_4 + Mg \rightarrow MgSO_4 + Cu$
   B: $MgSO_4 + CaCl_2 \rightarrow MgCl_2 + CaSO_4$
   C: $MgSO_4 + Na_2CO_3 \rightarrow MgCO_3 + Na_2SO_4$

7. In a single displacement reaction, there must be one element that is not part of a compound as a reactant and a different element that is not part of a compound as a product. In a double displacement reaction, there are two sets of compounds as reactants which are generally dissolved in water and two new compounds as products.

   The formation of a gas or (in this case) a precipitate often provides evidence of a double displacement reaction. In a single displacement reaction, black or grey metal deposits often appear (except in the case of dark reddish brown copper).

8. The products of the reaction will indicate which ions are present in the reaction and one can work backward following the patterns AB + C → AC + B or AB + CD → AD + BC can be determined. If a precipitate forms, students can infer that a double displacement reaction occurs if an element is formed the students can tell that the reactants contained an element and the reaction was a single displacement.

9. Neutralization of stomach acid with antacids is a double displacement reaction. Precipitation of gold from gold cyanide using zinc is a single displacement reaction used in the mining process. The thermite reaction $2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(\ell)$ is used for extracting iron from iron(III) oxide. Sulphuric acid is added to barium chloride to produce barium sulphate, which makes the salt barium sulphate precipitate easily. This is another double displacement reaction, which forms a salt solution which patients drink prior to having an X ray. This salt is used in X rays because it has low solubility and will not harm the human body while it provides a very high contrast media for imaging of the X ray.

Data Analysis Investigation 5-D Can Metals Be "Active"?

(Student textbook page 212)

Pedagogical Purpose

Students evaluate a list of observations to arrange metals into an activity series.

Planning	
Time	40 min

Background

In this investigation, students create an activity series for metals, which lists metals in order of reactivity from highest to lowest. It is used to determine the products of single displacement reactions. The reactivity series determines qualitative characteristics, such as the reactions with water, air, and acids.

Metals lose electrons to become positively charged ions called *cations*. Metals higher in the activity series will displace any metal below it in the series. This reaction occurs due to the difference in the stability of the electron arrangement of elemental metal atoms compared to metal cations. Metals that require the loss of only a single electron to form stable ions tend to be more reactive than similar metals that require the loss of more than one electron. For example, potassium has a valence electron in energy level four that it can lose to achieve a stable octet. This lone electron is far from the attractive forces of the positive nucleus and is easily lost from the atom. Whereas the precious metals (such as gold, silver, copper) cannot easily lose the required electrons to achieve the more stable octet structure. So, they are less reactive than potassium.

Activity Notes and Troubleshooting

- Encourage students to refer to Table 5.1 on page 197 of the student textbook when deciding which type of reaction has occurred.

Additional Support

- **DI** Provide molecular model kits for bodily-kinesthetic students to manipulate.
- **ELL** To model why some metals are more reactive than others, have students use cut outs or models of electrons and nuclei of atoms or simply draw large Bohr-Rutherford diagrams. Have students build potassium and place the electrons in the outer shells and build copper and place the electrons in the outer shells. Ask students to show what each atom would like to do in order to achieve an octet. They will see that potassium requires only the loss of one electron from the fourth energy level whereas copper requires the loss of multiple electrons from the same fourth energy level to achieve a stable octet. Students should see that the process is much more complicated for copper and as a result, copper does not easily oxidize (lose electrons) and is less reactive.

Answers

1. $Zn(s) + CuSO_4(aq) \rightarrow$ reaction occurs, zinc can displace copper ion and therefore it is more active
   $Zn(s) + Pb(NO_3)_2(aq) \rightarrow$ reaction occurs, zinc can displace lead ions and therefore it is more active
   $Pb(s) + AgNO_3(aq) \rightarrow$ reaction occurs, lead can displace silver ions and therefore it is more active and should be found above silver
   $Pb(s) + ZnCl_2(aq) \rightarrow$ no reaction, lead cannot displace zinc ions
   $Cu(s) + AgNO_3(aq) \rightarrow$ reaction occurs, copper can displace silver ions and should be found above silver
   $Cu(s) + Pb(NO_3)_2(aq) \rightarrow$ no reaction, copper cannot displace lead so must be below it
   $Ag(s) + CuSO_4(aq) \rightarrow$ no reaction, silver cannot displace copper ions so must be below it
   $Ag(s) + ZnCl(aq) \rightarrow$ no reaction, silver cannot displace zinc ions so must be below it

2.

	Cu^{2+}	Pb^{2+}	Ag^{+}	Zn^{2+}
Zn(s)	reaction	reaction		
Pb(s)			reaction	no reaction
Cu(s)		no reaction	reaction	
Ag(s)	no reaction			no reaction

3. zinc, lead, copper, silver

4. Example: I examined which metals reacted with which ions. When a reaction occurs it means the metal is able to displace the metal ion it is in contact with. Zinc reacted with copper and lead whereas silver did not react at all. Zinc metal was able to displace both copper and lead ions but lead could not displace zinc, therefore zinc must be more reactive and higher than copper and lead in the series. Copper metal was able to displace silver ions but silver could not displace copper metal, therefore silver must be on the bottom of the series. In addition, silver metal could not displace zinc ions therefore it reinforces that silver is not a very reactive metal and should be found on the bottom of the series.

5. $Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$
   $Zn(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Zn\ (NO_3)_2(aq)$
   $Pb(s) + AgNO_3(aq) \rightarrow Ag(s) + Pb(NO_3)_2(aq)$
   $Pb(s) + ZnCl_2(aq) \rightarrow$ no change
   $Cu(s) + AgNO_3(aq) \rightarrow Ag(s) + CuNO_3(aq)$
   $Cu(s) + Pb(NO_3)_2(aq) \rightarrow$ no change
   $Ag(s) + CuSO_4(aq) \rightarrow$ no change
   $Ag(s) + ZnCl(aq) \rightarrow$ no change