

**TOPIC 1:**  
**Reactions in AQUEOUS SOLUTIONS**

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## Topic 1: Reactions in Aqueous Solutions

- C12-1-01** Explain examples of solubility and precipitation at the particulate and symbolic levels.
- C12-1-02** Perform a laboratory activity to develop a set of solubility rules.
- C12-1-03** Use a table of solubility rules to predict the formation of a precipitate.
- C12-1-04** Write balanced neutralization reactions involving strong acids and bases.
- C12-1-05** Perform a laboratory activity to demonstrate the stoichiometry of a neutralization reaction between a strong base and a strong acid.
- C12-1-06** Calculate the concentration or volume of an acid or a base from the concentration and volume of an acid or a base required for neutralization.
- C12-1-07** Design and test a procedure to determine the identity of a variety of unknown solutions.
- C12-1-08** Outline the development of scientific understanding of oxidation and reduction reactions.  
Include: gain and loss of electrons, oxidizing agent, and reducing agent
- C12-1-09** Determine the oxidation numbers for atoms in compounds and ions.
- C12-1-10** Identify reactions as redox or non-redox.  
Include: oxidizing agent, reducing agent, oxidized substance, and reduced substance
- C12-1-11** Balance oxidation-reduction reactions using redox methods.  
Include: acidic and basic solutions
- C12-1-12** Research practical applications of redox reactions.  
*Examples: rocket fuels, fireworks, household bleach, photography, metal recovery from ores, steel making, aluminum recycling, fuel cells, batteries, tarnish removal, fruit clocks, forensic blood detection using luminol, chemiluminescence/bioluminescence, electrolytic cleaning, electrodeposition, photochemical etching, antioxidants/preservatives . . .*

**Suggested Time: 18 hours**

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

## SPECIFIC LEARNING OUTCOME

C12-1-01: Explain examples of solubility and precipitation at the particulate and symbolic levels.

(0.5 hour)

SLO: C12-1-01

## SUGGESTIONS FOR INSTRUCTION

## Entry-Level Knowledge

The solution process was addressed in detail in Grade 11 Chemistry (Topic 4: Solutions). Students explained the solution process of simple ionic and covalent compounds, using visual and particulate representations and chemical equations. Students performed a laboratory activity to illustrate the formation of solutions in terms of the polar and non-polar nature of substances, which included the terms *soluble* and *insoluble*.

## Assessing Prior Knowledge

Check for students' understanding of prior knowledge, and review concepts as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL (Know, Want to Know, Learned) strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share) found in Chapter 9 of *Senior Years Science Teachers' Handbook* (Manitoba Education and Training) – hereinafter referred to as *SYSTH*.

## TEACHER NOTES

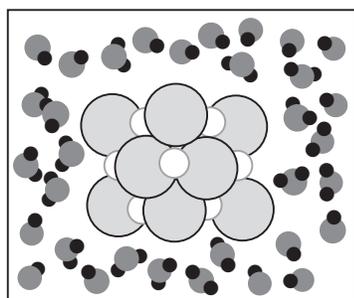
## Demonstration

Provide students with several examples of solutions and have them explain the solution process at the molecular level and the symbolic level. In this context, the term *molecular* is considered interchangeable with the term *particulate*.

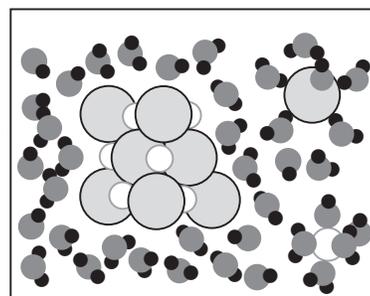
Example 1:  $\text{NaCl}_{(s)}$  dissolved in water

■ **Molecular level:**

$\text{NaCl}_{(s)} + \text{H}_2\text{O}_{(l)}$



$\text{NaCl}_{(aq)}$



## General Learning Outcome Connections

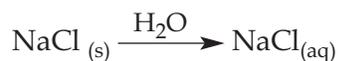
GLO D3: Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOME**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

- **Symbolic level:**



*Example 2:*  $\text{NaCl}_{(aq)}$  and  $\text{AgNO}_{3(aq)}$  combined together

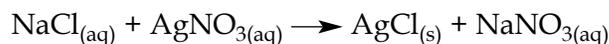
- **Molecular level:**

First show both solutions individually in their beakers. In beaker 1,  $\text{NaCl}_{(aq)}$  is drawn with the  $\text{Na}^+$  and  $\text{Cl}^-$  ions circulating amidst the water molecules. In beaker 2,  $\text{AgNO}_{3(aq)}$  is drawn with the  $\text{Ag}^+$  and  $\text{NO}_3^-$  ions floating around the water molecules.

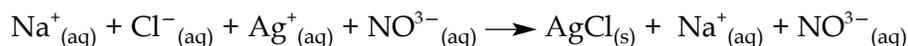
Then, in the third diagram, show the mixing of the two solutions. Students should see that the  $\text{Ag}^+$  ions will precipitate with the  $\text{Cl}^-$  ions, forming a white precipitate.

- **Symbolic level:**

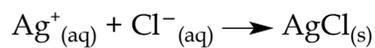
Molecular equation:



Ionic equation:



Net ionic equation:

**Animations**

Have students view animations of precipitation reactions online.

*Sample Website:*

Virtual Crezlab Qualitative Analysis. "Precipitation Reactions: Another Example of Precipitation Reaction." *Teaching Laboratory*. Crescent Girls' School.

<[www.crescent.edu.sg/crezlab/webpages/pptReaction4.htm](http://www.crescent.edu.sg/crezlab/webpages/pptReaction4.htm)> (18 Jan. 2012).

This animation shows the reaction that takes place between solutions of sodium chloride and silver nitrate.

**Note:** Not all mixtures of ions produce a precipitation reaction. For example, if we mix together a solution of sodium chloride ( $\text{NaCl}$ ) and a solution of potassium iodide ( $\text{KI}$ ), no precipitation will occur. All ions will stay in the solution.

**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOME**

**C12-1-01:** Explain examples of solubility and precipitation at the particulate and symbolic levels.

(continued)

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**SUGGESTIONS FOR ASSESSMENT**

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**Paper-and-Pencil Task**

Ask students to diagram various reactions, showing the reaction at the molecular (particulate) level and at the symbolic level.

**LEARNING RESOURCES LINKS**

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*Chemistry* (Chang 489)

*Chemistry* (Zumdahl and Zumdahl 133)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 136)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 455)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 169)

*Prentice Hall Chemistry* (Wilbraham, et al. 488)

**Website**

Virtual Crezlab Qualitative Analysis. "Precipitation Reactions: Another Example of Precipitation Reaction." *Teaching Laboratory*. Crescent Girls' School. <[www.crescent.edu.sg/crezlab/webpages/pptReaction4.htm](http://www.crescent.edu.sg/crezlab/webpages/pptReaction4.htm)> (18 Jan. 2012).

**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**SKILLS AND ATTITUDES OUTCOME**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

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**NOTES**

**Topic 1:  
Reactions in  
Aqueous Solutions****SPECIFIC LEARNING OUTCOME****C12-1-02:** Perform a laboratory activity to develop a set of solubility rules.

(2 hours)

SLO: C12-1-02

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

In Grade 9 Science (specific learning outcome S1-2-13), students defined the term *precipitate* and recognized the formation of a precipitate to be one of the indicators of a chemical change.

In Grade 10 Science (S2-2-07), students investigated double displacement reactions. Grade 11 Chemistry (Unit 4: Solutions) presented the concepts of species being soluble or insoluble. Concentration was also addressed in detail in Grade 11 Chemistry.

**Assessing Prior Knowledge**

Check for students' understanding of prior knowledge and review concepts as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share – see *SYSTH*, Chapter 9).

**TEACHER NOTES**

The following demonstration is meant to be an activation activity. Students will be able to review reactions they have studied in Grade 10 Science and in Grade 11 Chemistry. Encourage students to draw molecular representations of these reactions.

**General Learning Outcome Connections**

- GLO B3:** Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.
- GLO B5:** Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.
- GLO C1:** Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.
- GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
- GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.
- GLO C8:** Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

**SKILLS AND ATTITUDES OUTCOMES**

- C12-0-S1:** Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.  
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), and emergency equipment
- C12-0-S3:** Design and implement an investigation to answer a specific scientific question.  
Include: materials, independent and dependent variables, controls, methods, and safety considerations
- C12-0-S5:** Collect, record, organize, and display data using an appropriate format.  
*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*
- C12-0-S7:** Interpret patterns and trends in data, and infer and explain relationships.
- C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.  
Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction
- C12-0-A1:** Demonstrate confidence in their ability to carry out investigations in chemistry and to address STSE-related issues.
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**Demonstration**

Show students the reaction between potassium iodide and lead(II) nitrate, or between cobalt(II) chloride and a saturated calcium hydroxide solution (limewater). These double displacement reactions demonstrate two indicators of a chemical change (colour and precipitate formation). As an extension, have students predict the products of the reaction and balance the equation. Remind students that both solutions have a concentration, which is a numeric reflection of the moles of solute compared to the volume of solution. The precipitate produced by the reaction is insoluble, or slightly soluble, in the other aqueous product.

**Laboratory Activity**

Have students develop their own procedure to create a set of solubility rules. For this experiment, see Appendix 1.1A: Developing a Set of Solubility Rules: Lab Activity. Provide students with 0.1 mol/L solutions of various anions and cations so that they can observe whether precipitates are formed. These observations will help students develop a set of solubility rules for the positive and negative ions used in the lab activity. A list of the solubility rules can be found in Appendix 1.1B: Developing a Set of Solubility Rules: Lab Activity (Teacher Notes) and in the resources listed in the Learning Resources Links.

**SUGGESTIONS FOR ASSESSMENT**

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**Laboratory Report**

The lab activity could be assessed as a formal lab report using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12). Word processing and spreadsheet software could be used to prepare reports. Also refer to the Lab Report Assessment rubric in Appendix 11.

**Topic 1:  
Reactions in  
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**SPECIFIC LEARNING OUTCOME****C12-1-02:** Perform a laboratory activity to develop a set of solubility rules.*(continued)***Laboratory Skills**

Periodically and randomly review the lab skills of individual students, so that eventually all students are assessed. Sample checklists for assessing lab skills and work habits are available in *SYSTH* (6.10, 6.11).

**Paper-and-Pencil Task**

Students can report on why certain ions are insoluble or soluble.

**Journal Writing**

Have students answer the following question in their science journals:

Do you think that “solubility guidelines” might be a better phrase to use than “solubility rules”? Why or why not?

**Class Discussion**

Students can share their results with each other and come up with some general guidelines regarding the solubility of ions in solution. The students’ rules can then be reconfirmed by the solubility rules table.

**LEARNING RESOURCES LINKS**

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*Chemistry* (Chang 118)

*Chemistry* (Zumdahl and Zumdahl 150)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 142)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 920)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 161)

*Nelson Chemistry 12: College Preparation Teacher’s Resource* (Penrose, et al.)  
LSM 1.15–1: The Solubility Rules, 97

*Prentice Hall Chemistry* (Wilbraham, et al. 344)

**Investigations**

*Laboratory Manual for Chemistry: Experiments and Principles* (Davis, et al.)  
Experiment 17: Reactions between Ions in Aqueous Solutions, 50

*Microscale Chemistry Laboratory Manual* (Slater and Rayner-Canham)  
Experiment 20: Solubilities of Salts, 60

*Prentice Hall Chemistry: The Study of Matter, Laboratory Manual* (Wagner)  
Lab 31: Precipitates and Solubility Rules, 157

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-S1:** Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), and emergency equipment

**C12-0-S3:** Design and implement an investigation to answer a specific scientific question.

Include: materials, independent and dependent variables, controls, methods, and safety considerations

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

**C12-0-S7:** Interpret patterns and trends in data, and infer and explain relationships.

**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

**C12-0-A1:** Demonstrate confidence in their ability to carry out investigations in chemistry and to address STSE-related issues.

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**Appendices**

Appendix 1.1A: Developing a Set of Solubility Rules: Lab Activity

Appendix 1.1B: Developing a Set of Solubility Rules: Lab Activity  
(Teacher Notes)

**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**Topic 1:  
Reactions in  
Aqueous Solutions****SPECIFIC LEARNING OUTCOME****C12-1-03:** Use a table of solubility rules to predict the formation of a precipitate.**(1 hour)**

SLO: C12-1-03

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

In Grade 11 Chemistry (C11-4-03), students were introduced to the fact that when ionic compounds are placed in water, they dissociate (i.e., they separate into their ions). In Grade 10 Science (SLO S2-2-07), students classified reactions such as double displacement reactions. When solutions of two ionic compounds are placed into water, the ions will interact with each other and a double displacement reaction may occur. A precipitation reaction occurs when two aqueous solutions are mixed and a solid (precipitate) is formed. Refer to specific learning outcome C12-1-01 in Topic 1: Reactions in Aqueous Solutions, which addresses the process of double displacement reactions at the particulate level and the symbolic level.

**TEACHER NOTES**

Precipitation reactions are used in water treatment plants, in qualitative analysis, and as a preparation method for many salts. They are also a means by which limestone caverns are formed.

**Writing Net Ionic Equations**

Take students through the following steps to ensure that they will be able to write net ionic equations.

**General Learning Outcome Connections**

- GLO B3:** Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.
- GLO B5:** Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.
- GLO C1:** Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.
- GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
- GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.
- GLO C8:** Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.
- GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

## SKILLS AND ATTITUDES OUTCOMES

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .

**C12-0-S1:** Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), and emergency equipment

**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

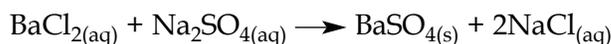
*Sample Problem:*

Write a net ionic equation for the reaction between  $\text{BaCl}_2$  and  $\text{Na}_2\text{SO}_4$ .

- Predict the products of the reaction and ensure that the equation is balanced.

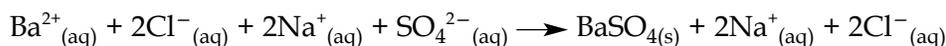


- Use Appendix 1.2: Solubility Rules to identify which ionic substances will precipitate from aqueous solutions. (Any chemistry text listed in the Learning Resources Links will have a table of rules.) Looking at these solubility rules, students should notice that the  $\text{Cl}^-$  ion is soluble with the  $\text{Na}^+$  ion. Therefore,  $\text{NaCl}$  will stay in solution; that is, it is written as  $\text{NaCl}_{(\text{aq})}$ . Students should also notice from the solubility rules that the  $\text{Ba}^{2+}$  ion forms an insoluble product with the  $\text{SO}_4^{2-}$  ion. Therefore,  $\text{BaSO}_4$  is written with a subscript  $_{(\text{s})}$ , as it forms a precipitate in the beaker. Those substances that form a precipitate should be followed by  $_{(\text{s})}$ , and those that do not form a precipitate should be followed by  $_{(\text{aq})}$ .



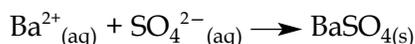
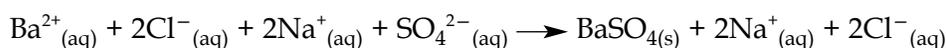
This is known as the *balanced molecular equation*.

- Recognize that soluble aqueous ionic compounds will dissociate into ions, whereas insoluble compounds will not. Students must make sure that their equation is balanced.



This is known as the *complete ionic equation, total ionic equation, or ionic equation*.

- Cancel out all spectator ions (those that appear on both sides of the equation), and rewrite the equation.



This is known as the *net ionic equation*.

See Appendix 1.3: Predicting Precipitation Reactions for more sample problems.

**Topic 1:  
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**SPECIFIC LEARNING OUTCOME****C12-1-03:** Use a table of solubility rules to predict the formation of a precipitate.*(continued)*

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**Animations**

A variety of animations of precipitation reactions are available online.

*Sample Websites:*

The North Carolina School of Science and Mathematics (NCSSM). Distance Education and Extended Programs. "Science Secondary Level." *STEM@NCSSM*. <[www.dlt.ncssm.edu/stem/sci-secondary](http://www.dlt.ncssm.edu/stem/sci-secondary)> (3 Aug. 2012).

Dozens of chemistry animations, images, documents, and videos can be found on this website.

\_\_\_\_\_. \_\_\_\_\_. "Chemistry Graphics – Moles." *Teacher's Instructional Graphics and Educational Resource (TIGER)*. <[www.dlt.ncssm.edu/stem/sci-secondary](http://www.dlt.ncssm.edu/stem/sci-secondary)> (18 Jan. 2012).

The animation entitled "DoubleDisp\_Reaction\_Precipitation.html (.exe or .mov)" shows the double displacement reaction between lead(II) nitrate and potassium iodide to form a slightly soluble precipitate.

Virtual Crezlab Qualitative Analysis. "Precipitation Reactions: Precipitation Explained." *Teaching Laboratory*. Crescent Girls' School. <[www.crescent.edu.sg/crezlab/webpages/pptReaction3.htm](http://www.crescent.edu.sg/crezlab/webpages/pptReaction3.htm)> (18 Jan. 2012).

This animation shows the precipitation reaction of lead(II) nitrate and potassium iodide.

**Laboratory Activity**

Provide students with well plates and four unknown solutions in dropper bottles. Students should be able to determine the identity of each solution, using experimentation, their solubility rules, and a colour chart (see Appendix 1.4: Colour Chart for Ions in Aqueous Solutions). For a sample procedure, see Appendix 1.5: Identifying Unknown Solutions (Teacher Notes and Preparation Guide).

**Discrepant Event**

If you have not already done the demonstration suggested for C12-1-01, show students that two clear solutions mixed together do not necessarily give a clear product (e.g., lead(II) nitrate and potassium iodide).

Alternatively, for a more environmentally friendly demonstration, show students a precipitation reaction with a variety of colours involved.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

**C12-0-S1:** Demonstrate work habits that ensure personal safety and the safety of others, as well as consideration for the environment.

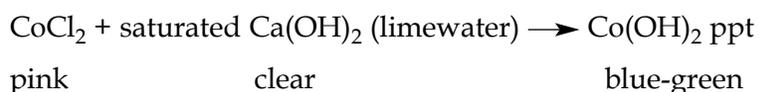
Include: knowledge and use of relevant safety precautions, Workplace Hazardous Materials Information System (WHMIS), and emergency equipment

**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

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*Example:*

**SUGGESTIONS FOR ASSESSMENT**

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**Paper-and-Pencil Task**

Have students use process notes to solve problems using a set of solubility rules to predict the potential formation of a precipitate in a double replacement reaction. For examples of problems, see Appendix 1.3: Predicting Precipitation Reactions.

**Laboratory Skills**

Periodically and randomly review the lab skills of individual students, so that eventually all students are assessed. Sample checklists for assessing lab skills and work habits are available in *SYSTH* (6.10, 6.11).

**Journal Writing/Process Notes**

Students can explain the steps to writing out net ionic equations in their science journals. See Appendix 1.6A: Process Notes for Writing Net Ionic Equations (Teacher Notes) and Appendix 1.6B: Process Notes for Writing Net Ionic Equations (BLM).

**Visual Displays**

Have students create a Word Cycle using the terms *ions*, *spectator ions*, *precipitate*, *molecular equation*, *total ionic equation*, *net ionic equation*, and *double displacement reaction* (see Word Cycle, *SYSTH* 10.21).

**Topic 1:  
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**SPECIFIC LEARNING OUTCOME**

**C12-1-03:** Use a table of solubility rules to predict the formation of a precipitate.

(continued)

**LEARNING RESOURCES LINKS**



*Chemistry* (Chang 118)

*Chemistry* (Zumdahl and Zumdahl 150)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 142)

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom)  
ChemLab Solution Identification, 456

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 290)

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al. 289)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 161)

*Nelson Chemistry 12: College Preparation Teacher's Resource* (Penrose, et al.)  
LSM 1.15-1: The Solubility Rules, 97

*Nelson Chemistry 12: College Preparation, Ontario Edition* (Davies, et al.)  
Using Solubility Rules to Predict Precipitate Formation, 54

*Prentice Hall Chemistry* (Wilbraham, et al. 344)

**Investigations**

*Glencoe Chemistry: Matter and Change* (Dingrando, et al.)  
MiniLab: Observing a Precipitate-Forming Reaction, 295

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al.)  
Investigation 8-A: The Solubility of Ionic Compounds, 283

*Prentice Hall Chemistry Today: Laboratory Manual* (Whitman and Zinck)  
Solutions and Solubility, 58

**Websites**

The North Carolina School of Science and Mathematics (NCSSM). Distance Education and Extended Programs. "Science Secondary Level." *STEM@NCSSM*. <[www.dlt.ncssm.edu/stem/sci-secondary](http://www.dlt.ncssm.edu/stem/sci-secondary)> (3 Aug. 2012).

\_\_\_\_\_. \_\_\_\_\_. "Chemistry Graphics – Moles." *Teacher's Instructional Graphics and Educational Resource (TIGER)*. <[www.dlt.ncssm.edu/tiger/chem2.htm#moles](http://www.dlt.ncssm.edu/tiger/chem2.htm#moles)> (18 Jan. 2012).

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**SKILLS AND ATTITUDES OUTCOMES**

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**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

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**Appendices**

Appendix 1.2: Solubility Rules

Appendix 1.3: Predicting Precipitation Reactions

Appendix 1.4: Colour Chart for Ions in Aqueous Solutions

Appendix 1.5: Identifying Unknown Solutions (Teacher Notes and Preparation Guide)

Appendix 1.6A: Process Notes for Writing Net Ionic Equations (Teacher Notes)

Appendix 1.6B: Process Notes for Writing Net Ionic Equations (BLM)

**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**Topic 1:  
Reactions in  
Aqueous Solutions**

**SPECIFIC LEARNING OUTCOMES**

**C12-1-04:** Write balanced neutralization reactions involving strong acids and bases.

**C12-1-05:** Perform a laboratory activity to demonstrate the stoichiometry of a neutralization reaction between a strong base and a strong acid.

(2.5 hours)

SLO: C12-1-04  
SLO: C12-1-05

**SUGGESTIONS FOR INSTRUCTION**

**Entry-Level Knowledge**

The following learning outcomes were addressed in Grade 10 Science:

S2-2-03: Write formulas and names of binary ionic compounds.

Include: IUPAC guidelines and rationale for their use

S2-2-06: Balance chemical equations.

Include: translation of word equations to balanced chemical equations, and balanced chemical equations to word equations

S2-2-10: Explain how acids and bases interact to form a salt and water in the process of neutralization.

In Grade 11 Chemistry (C11-3-03), students were shown how to write formulas and names for polyatomic compounds using International Union of Pure and Applied Chemistry (IUPAC) nomenclature.

**Assessing Prior Knowledge**

Check for students' prior knowledge and review concepts as necessary.

**TEACHER NOTES**

**Rules for Naming Binary and Polyatomic Acids**

Introduce the rules for naming binary and polyatomic acids.

To name binary acids, follow these steps:

1. Use the prefix *hydro-*.
2. Use the root of the anion.
3. Use the suffix *-ic*.
4. Use the word *acid* as the second word in the name.

**General Learning Outcome Connections**

**GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

**GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

**C12-0-S8:** Evaluate data and data-collection methods for accuracy and precision.

*Include: discrepancies in data, sources of error, and percent error*

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*Example 1:*

Naming a binary acid: HCl

1. hydro-
2. -chloride
3. -chloric
4. hydrochloric acid

To name polyatomic acids, follow a different set of rules. Many of the oxygen-rich polyatomic negative ions form acids that are named by replacing the suffix *-ate* with *-ic* and the suffix *-ite* with *-ous*. To name oxyacids (acids containing the element oxygen), students should be able to recognize oxyacids by the general formula  $H_aX_bO_c$ , where X represents an element other than hydrogen or oxygen. If enough  $H^+$  ions are added to a (root)ate polyatomic ion to completely neutralize its charge, the (root)ic acid is formed.

*Examples of polyatomic acids:*

$HNO_3$  (nitric acid) is formed by adding one  $H^+$  ion to nitrate,  $NO_3^-$

$H_2SO_4$  (sulphuric acid) is formed by adding two  $H^+$  ions to sulphate,  $SO_4^{2-}$

A *strong acid* completely dissociates into ions. This means that if 100 molecules of HCl are dissolved in water, 100 ions of  $H^+$  and 100 ions of  $Cl^-$  are produced.

Emphasize that there are only six strong acids: hydrochloric acid (HCl), hydrobromic acid (HBr), hydroiodic acid (HI), sulphuric acid ( $H_2SO_4$ ), nitric acid ( $HNO_3$ ), and perchloric acid ( $HClO_4$ ). Students should memorize the names of these acids, as this nomenclature forms the basis for naming other acids. Naming of other oxyacids and weak acids will be dealt with in Topic 5: Acids and Bases.

To name a base, the name of the metal is combined with the anion,  $OH^-$ , hydroxide ion. For example, NaOH would be named sodium hydroxide. A *strong base* completely dissociates into ions. This means that if 100 formula units of NaOH are dissolved in water, 100 ions of  $Na^+$  and 100 ions of  $OH^-$  are produced. Strong bases include any ionic compound that contains the hydroxide ( $OH^-$ ) ion. When combined with the hydroxide ion, elements found in groups 1 (IA) and 2 (IIA) form strong bases.

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**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOMES**

**C12-1-04:** Write balanced neutralization reactions involving strong acids and bases.

**C12-1-05:** Perform a laboratory activity to demonstrate the stoichiometry of a neutralization reaction between a strong base and a strong acid.

*(continued)*

These are the only acids and bases that students will be dealing with in Topic 1: Reactions in Aqueous Solutions.

When a strong acid and a strong base combine together they react completely. This means that all the hydrogen ions (from the acid) and all the hydroxide ions (from the base) will react to form water.

Remind students that acids and bases are ionic compounds, so that when placed into water, they will separate into their ions and undergo a double displacement reaction where a salt and water are formed.

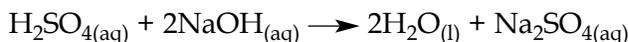
*Example 2:*

Write an equation for the neutralization reaction between  $\text{H}_2\text{SO}_4$  and  $\text{NaOH}$ .

- Predict the products of the reaction and ensure that the equation is balanced.

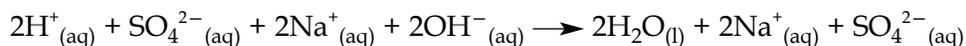


- Use the solubility rules to confirm whether each product will be aqueous, solid, or liquid.

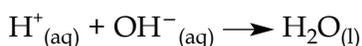
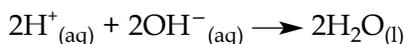
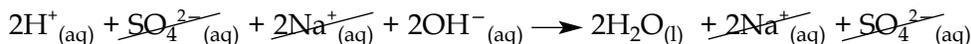


**Note:** Point out to students that water is a liquid, since aqueous solutions are dissolved in water.

- Write a total ionic equation, showing all ions that are in solution.



- Cancel the spectator ions and write the net ionic equation.



**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

**C12-0-S8:** Evaluate data and data-collection methods for accuracy and precision.

*Include: discrepancies in data, sources of error, and percent error*

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**Discrepant Event**

Show students that neutralization reactions can produce a greater volume than the sum of the volumes of the reactants. Traditional demonstrations include adding 125 mL of 0.1 mol/L HCl to 125 mL of 0.1 mol/L NaOH in a 250 mL graduated cylinder. An increase in volume of 2 to 3 mL should be observed. Have students explain this demonstration using particulate representations.

**Animations/Simulations**

Have students view online animations/simulations of neutralization reactions.

*Sample Websites:*

International Union of Pure and Applied Chemistry (IUPAC). Home Page.

[www.iupac.org](http://www.iupac.org) (18 Jan. 2012).

Virtual Crezlab Qualitative Analysis. "Acid-Base Reactions." *Teaching Laboratory*. Crescent Girls' School.

[www.crescent.edu.sg/crezlab/webpages/AcidReaction3.htm](http://www.crescent.edu.sg/crezlab/webpages/AcidReaction3.htm) (18 Jan. 2012).

This simulation demonstrates the neutralization reaction between sodium hydroxide and hydrogen chloride solutions. The spectator ions are also indicated in the simulation.

**TEACHER NOTES**

In Grade 10 Science, students worked with a 1:1 ratio for the neutralization reaction. In the following suggested lab activity, students will look at a 2:1 ratio. It is recommended that teachers avoid any discussion of Brønsted-Lowry acids and bases in addressing learning outcomes C12-1-04 and C12-1-05. A more in-depth titration will be done in Topic 5: Acids and Bases.

**Laboratory Activity**

Provide students with 0.1 mol/L solutions of NaOH and H<sub>2</sub>SO<sub>4</sub>. Have them perform a microscale titration so that they can compare the stoichiometric ratio to the experimental molar ratio between the reactants. Refer to Dispensing Drops from a Pipet onto a Reaction Surface (Waterman and Thompson 10). See Appendix 1.7A: Titration: Lab Activity and Appendix 1.7B: Titration: Lab Activity (Teacher Notes).

**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOMES**

**C12-1-04:** Write balanced neutralization reactions involving strong acids and bases.

**C12-1-05:** Perform a laboratory activity to demonstrate the stoichiometry of a neutralization reaction between a strong base and a strong acid.

(continued)

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**SUGGESTIONS FOR ASSESSMENT**

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**Process Notes**

Ask students to explain the steps involved in writing neutralization reactions using process notes. For an example, see Appendix 1.8: Process Notes for Balancing Neutralization Reactions.

**Paper-and-Pencil Task**

Students should be able to write balanced neutralization reactions.

**Laboratory Reports**

The lab activity could be assessed as a formal lab report using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12). Word processing and spreadsheet software could be used to prepare reports. Also refer to the Lab Report Assessment rubric in Appendix 11.

**Laboratory Skills**

Periodically and randomly review the lab skills of individual students, so that eventually all students are assessed. Assess skills such as ensuring consistent trials, proper use of a micropipette, and safe handling of chemicals. Sample checklists for assessing lab skills and work habits are available in *SYSTH* (6.10, 6.11).

**LEARNING RESOURCES LINKS**

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*Chemistry* (Chang 125)

*Chemistry* (Zumdahl and Zumdahl 161)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 144, 148)

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom 521)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 250, 295, 617)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 163, 224)

*Prentice Hall Chemistry* (Wilbraham, et al. 217, 612)

### SKILLS AND ATTITUDES OUTCOMES

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

**C12-0-S8:** Evaluate data and data-collection methods for accuracy and precision.

*Include: discrepancies in data, sources of error, and percent error*

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### Investigations

*Microscale Chemistry Laboratory Manual (Slater and Rayner-Canham)  
Volumetric Acid-Base Titration, 24*

*Prentice Hall Chemistry: Small-Scale Chemistry Laboratory Manual  
(Waterman and Thompson)  
Dispensing Drops from a Pipet onto a Reaction Surface, 10*

### Websites

International Union of Pure and Applied Chemistry (IUPAC). Home Page.  
<[www.iupac.org](http://www.iupac.org)> (18 Jan. 2012).

Virtual Crezlab Qualitative Analysis. "Acid-Base Reactions." *Teaching Laboratory*. Crescent Girls' School.  
<[www.crescent.edu.sg/crezlab/webpages/AcidReaction3.htm](http://www.crescent.edu.sg/crezlab/webpages/AcidReaction3.htm)>  
(18 Jan. 2012).

### Appendices

Appendix 1.7A: Titration: Lab Activity

Appendix 1.7B: Titration: Lab Activity (Teacher Notes)

Appendix 1.8: Process Notes for Balancing Neutralization Reactions

#### Selecting Learning Resources

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-06:** Calculate the concentration or volume of an acid or a base from the concentration and volume of an acid or a base required for neutralization.

(1 hour)

SLO: C12-1-06

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

In addressing learning outcome C12-1-05, students obtained experimental data related to the stoichiometry of a neutralization reaction between a strong base and a strong acid.

**Demonstrations/Activating Activity**

Before applying the suggested problem-solving strategy for sample neutralization problems, teachers can perform several acid-base demonstrations to activate students' interest. Have students write their observations on the chemical reaction taking place (i.e., first describe the reactants and then describe the resulting products).

The following list is a sample of the variety of demonstrations teachers can choose to perform. References for these demonstrations are given in the Learning Resources Links.

- **Orange Juice to Strawberry Float**

This demonstration involves mixing sodium bicarbonate and Alconox in water. Methyl orange indicator is added to this solution, which results in a solution similar to orange juice. Then hydrochloric acid is added quickly but very carefully. The reaction is very vigorous and produces a solution that looks like a strawberry float.

**Note:**

Because some of these demonstrations involve weak acids, students should not be asked to write balanced equations after they are shown.

**Caution:**

This is a very messy demonstration and strict safety precautions should be taken.

**General Learning Outcome Connections**

**GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.

**GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

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**■ pH Rainbow Tube**

This demonstration starts with a tube filled with green solution. At one end, a few drops of acid are added, and at the other end, a few drops of base are added. As a result, a whole spectrum of colours appears.

**■ Multi-Use for “MoM”**

For this demonstration, a mixture of magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ), also known as milk of magnesia, hydrochloric acid, and universal indicator shows a colour change from blue (basic) to red (acidic). The full colour range of universal indicator is shown during this process.

**■ Indicator Sponge**

This demonstration shows an indicator colour transition between pH 3 (blue) and pH 5 (red). Materials needed are a light-coloured cellulose sponge, a congo red indicator, sodium bicarbonate, and acetic or hydrochloric acid.

**■ Magic Pitcher Demo**

Several beakers are set up and, with the “magic pitcher,” students observe different colour changes in the beakers. The key to this demonstration is that all the beakers have had some drops of either acid or base, with varying concentrations, added to them.

**TEACHER NOTES**

Students can use the experimental data obtained in relation to learning outcome C12-1-04 to determine the unknown concentration of the acid or base. Teachers should de-emphasize the use of formulas such as  $C_1V_1 = C_2V_2$ . Also note that some chemistry texts use the following notation for concentration:  $M_1V_1 = M_2V_2$ . In American-based textbooks, it is common to see molarity (M) being used. In Grade 11 Chemistry (C11-4-13), the definition for *molarity* and *concentration* are given. Use mol/L as much as possible, as IUPAC no longer accepts M (molarity) as a unit. Refer to the following website for further information on correct terminology and units:

International Union of Pure and Applied Chemistry (IUPAC). Home Page.

<[www.iupac.org](http://www.iupac.org)> (18 Jan. 2012).

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-06:** Calculate the concentration or volume of an acid or a base from the concentration and volume of an acid or a base required for neutralization.

*(continued)***Problem-Solving Strategy**

To help students gain a better understanding of the concept of calculating the concentration or volume of an acid or a base, use the following process in solving neutralization problems:

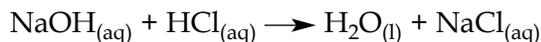
1. Write a balanced chemical equation for the reaction.
2. Use the concentration and volume of the known acid or base to calculate the moles of the substance.
3. Use the coefficients from the balanced equation to determine the moles of the unknown acid or base.
4. Calculate the required volume or concentration of the acid or base.

**Sample Neutralization Problems**

1. In the reaction of 35.0 mL of liquid drain cleaner containing sodium hydroxide (NaOH), 50.08 mL of 0.409 mol/L hydrochloric acid (HCl) must be added to neutralize the base. What is the concentration of the base in the cleaner?

*Solution:*

- a) Write a balanced equation.



- b) Calculate the number of moles of HCl by multiplying concentration by volume.

$$\begin{aligned} \text{mol HCl} &= (0.409 \text{ mol/L})(0.05008 \text{ L}) \\ &= 0.0205 \text{ mol HCl} \end{aligned}$$

- c) Use the balanced equation for the mole ratio between HCl and NaOH, and solve for the number of moles of NaOH.

$$\begin{aligned} \frac{1 \text{ mol NaOH}}{1 \text{ mol HCl}} &= \frac{x \text{ mol NaOH}}{0.0205 \text{ mol HCl}} \\ x \text{ mol NaOH} &= 0.0205 \cancel{\text{ mol HCl}} \times \frac{1 \text{ mol NaOH}}{1 \cancel{\text{ mol HCl}}} \\ x \text{ mol NaOH} &= 0.0205 \text{ moles NaOH} \end{aligned}$$

- d) Solve for the concentration of NaOH by dividing the number of moles by the volume given.

$$[\text{NaOH}] = \frac{0.0205 \text{ moles}}{0.0350 \text{ L}} = 0.586 \text{ mol/L}$$

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

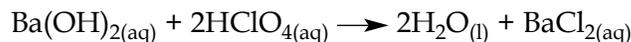
*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

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2. Calculate the volume of 0.256 mol/L Ba(OH)<sub>2</sub> that must be added to neutralize 46.0 mL of 0.407 mol/L HClO<sub>4</sub>.

*Solution:*

- a) Write a balanced equation.



- b) Calculate the number of moles of HClO<sub>4</sub> by multiplying concentration by volume.

$$\begin{aligned} \text{mol HClO}_4 &= (0.407 \text{ mol/L})(0.0460 \text{ L}) \\ &= 0.0187 \text{ mol HClO}_4 \end{aligned}$$

- c) Solve for the number of moles of Ba(OH)<sub>2</sub> by setting up the ratio, number of moles: coefficient from balanced equation.

$$\frac{\text{mol HClO}_4}{\text{coefficient HClO}_4} = \frac{\text{mol Ba(OH)}_2}{\text{coefficient Ba(OH)}_2}$$

$$\frac{0.0187 \text{ mol HClO}_4}{2 \text{ mol HClO}_4} = \frac{\text{mol Ba(OH)}_2}{1 \text{ mol Ba(OH)}_2}$$

$$0.00935 \text{ mol Ba(OH)}_2 = \text{mol Ba(OH)}_2$$

- d) Solve for the volume of Ba(OH)<sub>2</sub> by dividing the number of moles by the concentration.

$$V = \frac{\text{mol}}{C} = \frac{0.00935 \text{ mol}}{0.256 \text{ mol/L}} = 0.0365 \text{ L}$$

$$\text{Volume of Ba(OH)}_2 = 36.5 \text{ mL}$$

**SUGGESTIONS FOR ASSESSMENT**


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**Paper-and-Pencil Tasks**

1. Ask students to write down the steps for solving neutralization problems.
2. Provide students with a neutralization problem to solve. Use a process-notes format to have individuals share their thought processes for finding the mathematical solution to the problems.

The texts cited in the Learning Resources Links provide samples of problems in calculating for the concentration or the volume of given solutions.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-06:** Calculate the concentration or volume of an acid or a base from the concentration and volume of an acid or a base required for neutralization.

(continued)

**LEARNING RESOURCES LINKS**

*Chemistry* (Chang 145)

*Chemistry* (Zumdahl and Zumdahl 162)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 147)

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom 521)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 617)

*McGraw-Hill Ryerson Chemistry*, Combined Atlantic Edition (Mustoe, et al. 600)

*Prentice Hall Chemistry* (Wilbraham, et al. 612)

**Demonstrations**

Becker, Robert. "pH Rainbow Tube." *Chem 13 News* 190 (Dec. 1989).

\_\_\_\_\_. "pH Rainbow Tube." 1999. Flinn Scientific, Inc. Available on the Northern Kentucky University website at [www.nku.edu/~sieveb1/makeandtake2011.pdf](http://www.nku.edu/~sieveb1/makeandtake2011.pdf) (17 Apr. 2012).

Flinn Scientific, Inc. "Indicator Sponge: A Discrepant Event Demonstration." 2009. *Chem Fax!* <[www.flinnsci.com/Documents/demoPDFs/Chemistry/CF10376.pdf](http://www.flinnsci.com/Documents/demoPDFs/Chemistry/CF10376.pdf)> (18 May 2012).

\_\_\_\_\_. "Orange Juice to Strawberry Float: A Foamy Acid-Base Demonstration." 2010. *Chem Fax!* <[www.flinnsci.com/Documents/demoPDFs/Chemistry/CF0516.00.pdf](http://www.flinnsci.com/Documents/demoPDFs/Chemistry/CF0516.00.pdf)> (17 Apr. 2012).

\_\_\_\_\_. *Orange Juice to Strawberry Float*. 2009. YouTube. <[www.youtube.com/watch?v=UVdbG9-mHyc&feature=BFa&list=ULUVdbG9-mHyc&lf=channel](http://www.youtube.com/watch?v=UVdbG9-mHyc&feature=BFa&list=ULUVdbG9-mHyc&lf=channel)> (17 Apr. 2012).

Gross, George, et al. "Indicator Sponge." *A Demo a Day: A Year of Chemical Demonstrations*. Ed. Borislav Bilash II, George R. Gross, and John K. Koob. Batavia, IL: Flinn Scientific, Inc., 1995.

Tanis, Dave. *Demonstrations in Chemistry Classrooms*, Michigan Science Teachers Association Conference. 14 Mar. 2003. <<http://alittlecreation.com/science/Chemistry/tanis-chem.pdf>> (6 Aug. 2010).

This resource describes the following demonstrations:

- Sconzo, Penny. "Multi-Use for MOM." *Flinn Workshop Materials*. Batavia, IL: Flinn Scientific Foundation, 2001. Page 29.
- Becker, Bob. "Magic Pitcher Demo." *Flinn Workshop Materials*. Batavia, IL: Flinn Scientific, Inc., 2001. Page 54.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

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**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**Topic 1:  
Reactions in  
Aqueous Solutions****SPECIFIC LEARNING OUTCOME****C12-1-07:** Design and test a procedure to determine the identity of a variety of unknown solutions.**(2 hours)**

SLO: C12-1-07

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

Students should be able to use the concepts addressed in the previous learning outcomes to proceed with the lab activity that follows.

**TEACHER NOTES**

The solutions for the following lab activity should be prepared well in advance of the actual lab period. Hand out the lab guidelines a week before students perform the lab activity so they can research the possible products for each reaction (see Appendix 1.9A: Test Tube Mystery: Lab Activity [Guidelines]). Have students submit their plans a few days before the lab activity is conducted and check whether their plans are viable. Students can prepare for the lab activity by searching the Internet for information on their solutions, using key terms such as “test tube mystery,” “identification of unknowns,” and “unknown ionic solutions.” Remind students that the solubility chart and litmus tests can be used for acid and base identification. The colour and odour of solutions can also be used to identify the unknowns. Students who have prepared for the lab activity will have a better chance of being successful in identifying the unknowns.

Consult Appendix 1.9B: Test Tube Mystery: Lab Activity (Preparation Guide) for information on preparing for this lab activity before assigning it to students. A “possible” solution set is also provided in Appendix 1.9B. Teacher keys are available in Appendix 1.9C: Test Tube Mystery: Lab Activity (Teacher Key 1), which provides a sample grid of what students would bring to the lab, and in Appendix 1.9D: Test Tube Mystery: Lab Activity (Teacher Key 2), which provides a detailed synopsis of expected student observations post-lab.

**General Learning Outcome Connections**

- GLO C1:** Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.
- GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
- GLO C4:** Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information.
- GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.
- GLO C8:** Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life.

### SKILLS AND ATTITUDES OUTCOMES

**C12-0-S3:** Design and implement an investigation to answer a specific scientific question.

Include: materials, independent and dependent variables, controls, methods, and safety considerations

**C12-0-S4:** Select and use scientific equipment appropriately and safely.

Examples: volumetric glassware, balance, thermometer . . .

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .

**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

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### Laboratory Activity

Provide students with 12 unlabelled samples of the solutions listed in Appendix 1.9B: Test Tube Mystery: Lab Activity (Preparation Guide).

Have students determine the identity of each solution using solubility rules, observation of colour and odour, flame tests, and litmus paper. See Appendix 1.9A: Test Tube Mystery: Lab Activity (Guidelines).

### SUGGESTIONS FOR ASSESSMENT

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#### Laboratory Reports

The suggested lab activity could be assessed as a formal lab report using the Laboratory Report Outline or the Laboratory Report Format (see *SYSTH* 11.38, 14.12). Word processing and spreadsheet software could be used to prepare reports. Also see the Lab Report Assessment rubric in Appendix 11.

#### Laboratory Skills

Create a short skill-based rubric to assess a predetermined set of lab skills. See Appendix 11 for a variety of rubrics and checklists that can be used for self-assessment, peer assessment, and teacher assessment.

Periodically and randomly review the lab skills of individual students, so that eventually all students are assessed. Sample checklists for assessing lab skills and work habits are available in *SYSTH* (6.10, 6.11).

**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOME**

**C12-1-07:** Design and test a procedure to determine the identity of a variety of unknown solutions.

(continued)

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**LEARNING RESOURCES LINKS**

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*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 617)

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al. 600)

*Prentice Hall Chemistry* (Wilbraham, et al. 612)

**Investigations**

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom)  
ChemLab: Solution Identification, 456

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al.)

Thought Lab 7.1: Identifying Unknown Aqueous Solutions, 267

**Appendices**

Appendix 1.9A: Test Tube Mystery: Lab Activity (Guidelines)

Appendix 1.9B: Test Tube Mystery: Lab Activity (Preparation Guide)

Appendix 1.9C: Test Tube Mystery: Lab Activity (Teacher Key 1)

Appendix 1.9D: Test Tube Mystery: Lab Activity (Teacher Key 2)

**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-S3:** Design and implement an investigation to answer a specific scientific question.

Include: materials, independent and dependent variables, controls, methods, and safety considerations

**C12-0-S4:** Select and use scientific equipment appropriately and safely.

*Examples: volumetric glassware, balance, thermometer . . .*

**C12-0-S5:** Collect, record, organize, and display data using an appropriate format.

*Examples: labelled diagrams, graphs, multimedia applications, software integration, probeware . . .*

**C12-0-S9:** Draw a conclusion based on the analysis and interpretation of data.

Include: cause-and-effect relationships, alternative explanations, and supporting or rejecting a hypothesis or prediction

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**NOTES**

**Topic 1:  
Reactions in  
Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-08:** Outline the development of scientific understanding of oxidation and reduction reactions.

Include: gain and loss of electrons, oxidizing agent, and reducing agent

(0.5 hour)

SLO: C12-1-08

**SUGGESTIONS FOR INSTRUCTION**

**Entry-Level Knowledge**

In Grade 10 Science (S2-2-01, S2-2-02, S2-2-03, and S2-2-04), students were shown the significance of the electron and nuclear charge with respect to periodicity and the reaction between elements to produce ionic and covalent compounds.

In addressing specific learning outcome C12-1-08, students develop an understanding of how loss and gain of electrons can be considered to be either an oxidation process or a reduction process.

**Assessing Prior Knowledge**

Check for students' understanding of prior knowledge and review concepts as necessary. Prior knowledge can be reviewed and/or assessed by using any of the KWL strategies (e.g., Concept Map, Knowledge Chart, Think-Pair-Share – see *SYSTH*, Chapter 9).

**Demonstration/Activating Activity**

The following demonstration can be performed to introduce this learning outcome. Place 20 g of copper(II) chloride dihydrate ( $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ ) in a 250 mL beaker and dissolve it in 175 mL of water. Loosely crumple a 10 cm  $\times$  10 cm piece of aluminum foil and place it in the solution.

Encourage students to note their observations carefully at the macro level for later discussions related to activity at the molecular level. For instance, ask students whether an aluminum tank could be used to transport a  $\text{CuCl}_2$  solution. Students could also explain why the following reaction does not occur:  $\text{Cu}_{(s)} + \text{AlCl}_{3(aq)}$ .

**Caution:**

This reaction is exothermic, so use precautions. Provide for adequate ventilation or use a fume hood.

**General Learning Outcome Connections**

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

---

**TEACHER NOTES**

The information presented for learning outcome C12-1-12 should provide teachers with enough information to motivate students to learn more about the underlying processes or factors that cause oxidation and reduction reactions to occur (e.g., rocket propulsion, fireworks, antioxidants, photosynthesis, rusting, breathalyzers, to name a few of the applications).

**Oxidation and Reduction**

Oxidation and reduction reactions and the loss and gain of electrons have been studied since the early 1800s. Scientists have focused on oxidation and reduction reactions and the movement of electrons in addressing the energy crisis and the struggle against climate change on our planet.

Many scientists believe that hydrogen cells and fuel cells are the way of the future. If students are to make environmentally sound choices for the future, they should understand the current electrochemical technologies they will be using. Provide students with a brief overview of these technologies as a preparation for a detailed discussion of electrochemistry in Topic 6: Electrochemistry.

The term *oxidation* was first applied to the combining of oxygen with other elements (e.g., rusting iron or burning carbon or methane). Burning is another name for rapid oxidation.

The term *reduction* originally meant the removal of oxygen from a compound. It comes from the fact that the free metal has a lower mass than its oxide compound. There is a decrease or reduction in the mass of the material as the oxygen is removed.

**Differentiating between Oxidation and Reduction: Examples**

From their prior knowledge, students should have some familiarity with oxidation through burning, or combustion, and the rotting of food. Students should have observed the burning of magnesium metal in Grade 11 Chemistry. Remind students that burning, or combustion, is the reaction of a substance with the oxygen gas in the air.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

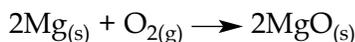
**SPECIFIC LEARNING OUTCOME**

**C12-1-08:** Outline the development of scientific understanding of oxidation and reduction reactions.

Include: gain and loss of electrons, oxidizing agent, and reducing agent

(continued)

Example 1:



If this reaction is written in ionic form, it becomes



Observations

- Non-scientists usually refer to this reaction as burning, or combustion, but scientists refer to it as oxidation.
- Both magnesium and oxygen gases are elements and have no charge.
- The magnesium has been oxidized to MgO by the reaction with oxygen gas.
- Considering the charges, the metal has gone from 0 charge to 2+ charge, and the non-metal from 0 charge to 2- charge.

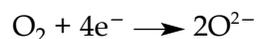
Historically, chemists recognized that other non-metallic elements unite with substances in a manner similar to that of oxygen (e.g., hydrogen, antimony, and sodium will burn in chlorine, iron will burn in fluorine). Therefore, the terms *oxidation* and *reduction* were redefined as follows:

- **Oxidation:** the process by which electrons are removed from an atom or ion.
- **Reduction:** the process by which any atom or ion gains electrons.

If we look at the change in ion charge as a function of electrons, the following relationships can be written as

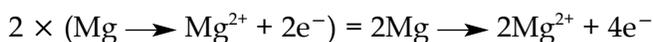


In this equation, charge is conserved.  
There is 0 charge on both sides.

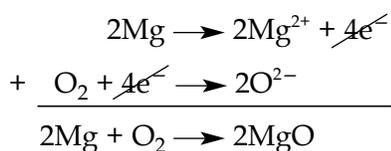


In this equation, charge is conserved.  
There is 4<sup>-</sup> charge on both sides.

By doubling the Mg relationship, the electrons are lost by the Mg and gained by the oxygen balance.



This results in the balanced equation



**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

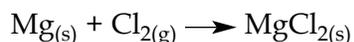
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Using this example, we could say that Mg is oxidized (combines with oxygen).

- Mg gains a positive charge by becoming an ion.
- This change occurs by a loss of electrons.

Can we apply these generalizations to other reactions?

*Example 2:*



If this reaction is written in ionic form, it becomes

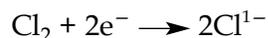


Recall that  $2\text{Cl}^{1-}$  ions are required to balance the  $2+$  charges of the Mg ion to form  $\text{MgCl}_2$ .

As in the first example, we can write the reaction as an ionic representation.



In this equation, charge is conserved.  
There is 0 charge on both sides.



In this equation, charge is conserved.  
There is  $2^-$  charge on both sides.

Using this example, we could say that Mg is again oxidized.

- Mg gains a positive charge to become an ion.
- This change occurs by a loss of electrons.

A complementary reaction is that a Cl atom becomes a  $\text{Cl}^{1-}$ .

- Cl is reduced to a negative ion.
- This change occurs by a gain of electrons.

Based on these generalizations, chemists have defined *oxidation* as a loss of electrons, and *reduction* as a gain of electrons.

Mnemonics such as the following may help students differentiate between oxidation and reduction:

- OIL RIG – oxidation is losing and reduction is gaining
- LEO GER – losing electrons oxidation and gaining electrons reduction

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

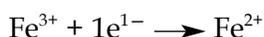
**SPECIFIC LEARNING OUTCOME**

**C12-1-08:** Outline the development of scientific understanding of oxidation and reduction reactions.

Include: gain and loss of electrons, oxidizing agent, and reducing agent

(continued)

Example 3:



Gain of electrons – reduction



Loss of electrons – oxidation

There are basically two types of chemical reactions: those that do not have any apparent electron change and those that do. The second type of chemical reaction, in which electrons are transferred (lost or gained) between reactants, is called an *oxidation-reduction reaction* or a *redox reaction*.

**Animations/Simulations**

Have students view online animations or simulations illustrating a redox reaction at the molecular level.

Sample Website:

Chemical Education Research Group, Iowa State University. "Chemistry Experiment Simulations and Conceptual Computer Animations." *Chemical Education*. <<http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/simDownload/index4.html>> (22 Nov. 2012).

In the Electrochemistry section, download and unzip the following animations:

- Zinc Copper REDOX Transfer
- Lead Silver REDOX Transfer

In the Electrochemistry section, download and unzip the following simulation:

- Reactions of Metals and Metal Ions Experiment

In this simulation, electrons are transferred from zinc atoms to copper(II) ions. The animation shows electron exchange at the particulate level and gives a detailed explanation of the process occurring.

**Compare and Contrast**

Have students start working on Appendix 1.10A: Compare and Contrast Oxidation and Reduction. Students will be able to complete this frame once they have been introduced to learning outcome C12-1-09.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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**SUGGESTIONS FOR ASSESSMENT**

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**Paper-and-Pencil Tasks**

1. Give students an example of a chemical reaction and ask them to identify the substance being oxidized and the substance being reduced, as well as determine the numbers of electrons lost and gained to conserve charge. Students should be able to write the half-reactions; however, at this point, teachers would not likely use the term.

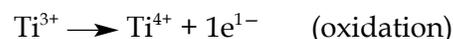
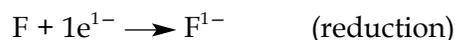
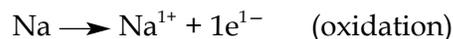
Examples of chemical reactions such as the following can be drawn from Grade 11 Chemistry:



Based on their prior knowledge, students can remove spectator ions from reactions.

2. Ask students to determine which of the following are oxidation reactions and which are reduction reactions. Students should be able to explain their answers.

*Examples:*



3. Have students answer the following question:

Why must oxidation and reduction reactions occur together?

**Topic 1:  
Reactions in  
Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-08:** Outline the development of scientific understanding of oxidation and reduction reactions.

Include: gain and loss of electrons, oxidizing agent, and reducing agent

(continued)

**LEARNING RESOURCES LINKS**



*Chemistry* (Chang 127)

*Chemistry* (Zumdahl and Zumdahl 164)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 151)

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom 556)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al. 637, 657)

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al. 713)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 434)

*Nelson Chemistry 12, Ontario Edition* (van Kessel, 652)

*Nelson Chemistry 12: College Preparation, Ontario Edition* (Davies, et al.)  
Particulate Representation, 374

*Prentice Hall Chemistry* (Wilbraham, et al. 631)

**Demonstration**

*Merrill Chemistry: A Modern Course, Teacher Annotated Edition* (Smoot, Price, and Smith 507)

**Website**

Chemical Education Research Group, Iowa State University. "Chemistry Experiment Simulations and Conceptual Computer Animations." *Chemical Education*. <<http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/simDownload/index4.html>> (22 Nov. 2012).

Animations: Zinc Copper REDOX Transfer

Lead Silver REDOX Transfer

Simulation: Reactions of Metals and Metal Ions Experiment

**Appendices**

Appendix 1.10A: Compare and Contrast Oxidation and Reduction

Appendix 1.10B: Compare and Contrast Oxidation and Reduction (Sample Response)

**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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**NOTES**

**Topic 1:  
Reactions in  
Aqueous Solutions****SPECIFIC LEARNING OUTCOME****C12-1-09:** Determine the oxidation numbers for atoms in compounds and ions.**(1 hour)**

SLO: C12-1-09

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

Students should be familiar with the concepts of oxidation and reduction from learning outcome C12-1-08.

**TEACHER NOTES**

Now that students can differentiate between oxidation and reduction reactions, give them an opportunity to discover that in complex reactions it is not always obvious what is being reduced or oxidized.

Chemists have created a set of rules to allow us to determine more easily the oxidation number of a given element within a compound or complex ion.

All chemistry texts provide rules for assigning oxidation numbers. Although the rules provided in texts will vary slightly, they will give the same value for oxidation numbers. One such set of rules is provided in Appendix 1.11: Oxidation Number Rules.

Remind students that the ion charge is written as  $2+$ , whereas the oxidation number is written as  $+2$ .

**Determining Oxidation Numbers: Examples**

There are many ways to set up or explain the arithmetic process for finding oxidation numbers. One such method is illustrated in the following examples, using the nine rules identified in Appendix 1.11: Oxidation Number Rules. See the Teacher Background notes that follow the examples.

For the following examples, determine the oxidation number of the elements written in **bold**.

**General Learning Outcome Connections**

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

*Example 1:*



Rule 4 tells us that the oxidation number of  $\text{H}^{1+} = +1$ , and rule 5 tells us that  $\text{O}^{2-} = -2$ . These numbers can be written in the appropriate places as indicated.

The total charge is calculated on the bottom (i.e., for H,  $+1 \times 1 = +1$ ; for O,  $-2 \times 3 = -6$ ).

+1	?	-2
H	N	O <sub>3</sub>
+1	?	-6

The oxidation numbers are written on top.

The total charges are written on the bottom.

Rule 3 tells us the sum of the bottom charges must be 0.

Thus, the unknown (?) on the bottom line must be +5.

+1	?	-2
H	N	O <sub>3</sub>
+1	+5	-6

Since there is only one N, the oxidation number of N must be +5.

+1	+5	-2
H	N	O <sub>3</sub>
+1	+5	-6

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-09:** Determine the oxidation numbers for atoms in compounds and ions.

(continued)

Example 2:



Rule 6 tells us that the oxidation number of  $\text{Na}^{1+} = +1$ , and rule 5 tells us that  $\text{O}^{2-} = -2$ . These numbers can be written in the appropriate places as indicated.

The total charge is calculated on the bottom (i.e., for O,  $-2 \times 4 = -8$ ; for Na,  $+1 \times 3 = +3$ ).

+1	?	-2
Na <sub>3</sub>	<b>P</b>	O <sub>4</sub>
+3	?	-8

The oxidation numbers are written on top.

The total charges are written on the bottom.

Rule 3 tells us the sum of the bottom charges must be 0.

Thus, the unknown (?) on the bottom line must be +5.

+1	?	-2
Na <sub>3</sub>	<b>P</b>	O <sub>4</sub>
+3	<b>+5</b>	-8

Since there is only one **P**, the oxidation number of **P** must be +5.

+1	<b>+5</b>	-2
Na <sub>3</sub>	<b>P</b>	O <sub>4</sub>
+3	+5	-8

**SKILLS AND ATTITUDES OUTCOMES**

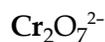
**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

*Example 3:*



This is a complex ion with an overall charge of 2-. This time the bottom charges must sum 2-. Rule 5 tells us  $\text{O}^{2-} = -2$ .

?	-2	
$\text{Cr}_2$	$\text{O}_7^{2-}$	
?	-14	

According to rule 3,  $-14 + ? = -2$ ; therefore, the unknown (?) must be +12.

?	-2	
$\text{Cr}_2$	$\text{O}_7^{2-}$	
<b>+12</b>	-14	

However, there are 2 Cr atoms; therefore, the oxidation number of each Cr must be +6.

<b>+6</b>	-2	
$\text{Cr}_2$	$\text{O}_7^{2-}$	
<b>+12</b>	-14	

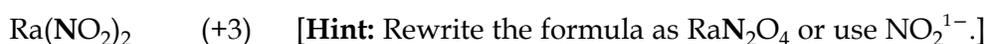
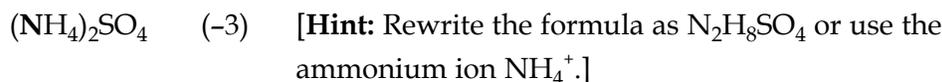
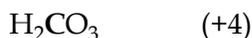
**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

## SPECIFIC LEARNING OUTCOME

C12-1-09: Determine the oxidation numbers for atoms in compounds and ions.

(continued)

*Other Examples:*



This method is more visual in nature than other methods. Some chemistry texts use a purely algebraic solution that will work for some students.

### Teacher Background

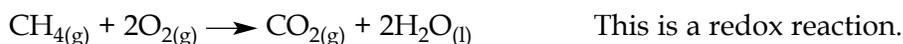
Many chemistry texts mention the oxidation states of hydrides, peroxides, and superoxides. This background information should assist teachers in giving students clear explanations, and should be considered for an extension or enrichment learning experience.

1. **Ionic hydrides** occur when hydrogen reacts with a reactive metal, such as the alkali metals or alkaline earth family.

*Examples:*



2. **Covalent hydrides** occur when the hydrogen atom is covalently bonded to the atom of another element. There are two types of covalent hydrides: those containing discrete molecular units, such as  $\text{CH}_4$  and  $\text{NH}_3$ , and those that have more complex structures, such as  $(\text{BeH}_2)_x$  and  $(\text{AlH}_3)_x$ .



The carbon in  $\text{CH}_4$  has an oxidation number of  $-4$  going to  $+4$  in  $\text{CO}_2$ , whereas the oxygen atom goes from  $0$  in free oxygen to  $-2$  in both  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .

3. **Ionic peroxides** are usually listed as an exception to the normal rules for assigning oxidation numbers for oxygen. They are known for the alkali metals: calcium, strontium, and barium. The ionic peroxides with water or dilute acids produce  $\text{H}_2\text{O}_2$ , and are powerful oxidizing agents.

The peroxide ion is  $\text{O}_2^{2-}$ , in which the O atom has a  $-1$  oxidation number.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

4. **Superoxides** are a group of compounds that contain the  $\text{O}_2^-$  ion. Under excess  $\text{O}_2$  conditions, alkali metals will undergo combustion reactions that generate several different products: oxides, peroxides, and superoxides. The superoxide ion  $\text{O}_2^-$  and, therefore, the O atom have an oxidation number of  $-\frac{1}{2}$ .

Potassium, rubidium, and cesium form stable, solid superoxide compounds that decompose when they contact water, releasing  $\text{O}_2$  gas. This reaction is used in specialized breathing equipment. Moisture from a person's breath will start the reaction, releasing oxygen gas:



Furthermore,  $\text{KO}_2$  will react with  $\text{CO}_2$  in the breath to release even more oxygen:



As always, work through all examples before assigning them to students in case fractional oxidation numbers arise. This may not be a problem in relation to learning outcome C12-1-09, but it could provide a challenge when students are balancing redox reactions in addressing learning outcome C12-1-10 (e.g.,  $\text{Fe}_3\text{O}_4$ , where the oxidation number of Fe would be  $+8/3$ ).

**Identifying Oxidation Numbers**

Have students identify the oxidation number for sulphur in each of the following compounds:  $\text{Na}_2\text{SO}_4$ ,  $\text{H}_2\text{S}$ ,  $\text{S}$ ,  $\text{S}_2\text{Cl}_2$ ,  $\text{SO}_2$ , and  $\text{K}_2\text{S}_2\text{O}_3$ . Ask them to organize these substances in order of increasing oxidation number (Dingrando, et al., *Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* 641).

**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOME****C12-1-09:** Determine the oxidation numbers for atoms in compounds and ions.*(continued)*

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**SUGGESTIONS FOR ASSESSMENT**

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**Paper-and-Pencil Tasks**

1. Students should be able to determine the oxidation numbers for atoms in compounds and ions. A host of chemistry texts contain examples for students to practise assigning oxidation numbers. Students can be presented with sealed test tubes of substances with the formulas of the substances listed on the test tubes.

Students can determine the oxidation number for each atom that is given in the chemical formula (Dingrando, et al., *Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* 643).

2. Have students complete Appendix 1.10A: Compare and Contrast Oxidation and Reduction, which they started in relation to learning outcome C12-1-08 (see Appendix 1.10B for a sample response).

**Journal Writing**

Ask students to propose how the rotting of food relates to oxidation and combustion. Ask them to explain how burning and rusting are similar and yet quite different.

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**LEARNING RESOURCES LINKS**

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*Glencoe Chemistry: Matter and Change* (Dingrando, et al.)  
Determining Oxidation Numbers, 641  
Oxidation Number in Redox Reactions, 643

*Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* (Dingrando, et al. 641, 643)

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al.)  
Oxidation Numbers, 721

*Nelson Chemistry 12: College Preparation, Ontario Edition* (Davies, et al.)  
5.2: Redox Reactions of Nonmetals, 379

*Prentice Hall Chemistry* (Wilbraham, et al.)  
Section 20.2: Oxidation Numbers, 639

**Appendices**

Appendix 1.10A: Compare and Contrast Oxidation and Reduction

Appendix 1.10B: Compare and Contrast Oxidation and Reduction (Sample Response)

Appendix 1.11: Oxidation Number Rules

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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**Selecting Learning Resources**

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

**Topic 1:  
Reactions in  
Aqueous Solutions****SPECIFIC LEARNING OUTCOME****C12-1-10:** Identify reactions as redox or non-redox.

Include: oxidizing agent, reducing agent, oxidized substance, and reduced substance

**(0.5 hour)**

SLO: C12-1-10

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

Students should be familiar with the concepts of oxidation and reduction from learning outcome C12-1-09.

In Grade 10 (S2-2-06), students were introduced to the conservation of atoms in a reaction, and in Grade 11 Chemistry (C11-3-05, C11-3-12, and C11-3-13), they learned about the conservation of atoms and mass during a chemical reaction.

**Assessing Prior Knowledge**

Check for students' understanding of prior knowledge and review concepts as necessary.

**Demonstrations**

Prepare a beaker of weak silver nitrate solution and add to it a length of coiled bare copper wire. Have students observe (and recall from Grade 11 Chemistry) the chemical reaction that occurs. Can they propose an explanation? Does the reverse reaction occur?

Use a weak solution of copper nitrate and silver metal to demonstrate the non-spontaneous reverse reaction of the above demonstration.

Demonstrate a number of reactive solutions involving oxidation-reduction (e.g., copper plus zinc sulphate and zinc plus copper sulphate). The choices that are farther apart on the Standard Reduction Potentials table would result in faster reactions. Illustrate this concept with enough detailed examples (such as the one that follows) to ensure students thoroughly understand the concept of oxidation and reduction and loss and gain of electrons. This understanding is critical to their success in Topic 6: Electrochemistry.

**General Learning Outcome Connections**

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

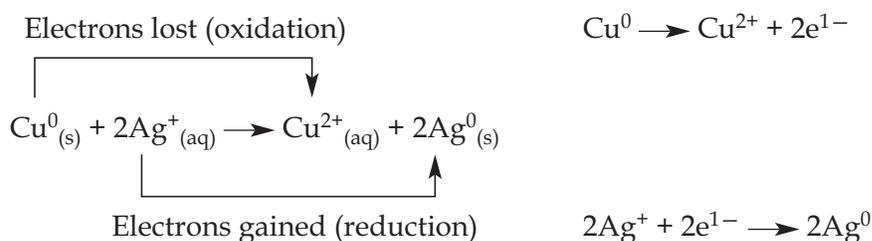
*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

*Example:*

Ionic equation:



Net ionic equation:



Note the following:

- A reducing agent causes the reduction of another species.
- An oxidizing agent causes the oxidation of another species.
- The substance being oxidized,  $\text{Cu}^0$ , is the reducing agent (also called an electron donor).
- The substance being reduced,  $\text{Ag}^+$ , is the oxidizing agent (also called an electron acceptor).

Some chemistry texts refer to *oxidation* as an increase in the oxidation state, whereas *reduction* is a reduction in the oxidation state.

Notice that each solid copper metal atom loses two electrons to form a copper(II) ion. Two silver ions pick up one of each of the copper electrons to form two silver atoms. The copper is oxidized and the silver is reduced – an oxidation-reduction electron transfer reaction (a redox reaction).

Each loss of electrons from a molecule must be offset by an equal gain of electrons in another molecule. Oxidation and reduction always accompany each other in reactions. They occur simultaneously. If a reaction does not have any transfer of electrons, it cannot be considered to be a redox reaction.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-10:** Identify reactions as redox or non-redox.

Include: oxidizing agent, reducing agent, oxidized substance, and reduced substance

(continued)

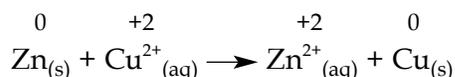
**Sample Problem**

For the reaction,  $\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \rightarrow \text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)}$ , indicate the following:

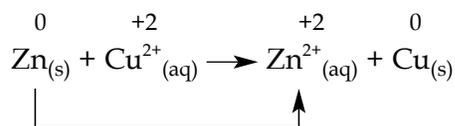
- State whether it is a redox or non-redox reaction.
- If it is a redox reaction, identify the oxidized substance, the reduced substance, the oxidizing agent, and the reducing agent.

*Solution:*

Step 1: Assign oxidation numbers to each substance based on the rules for assigning oxidation numbers.

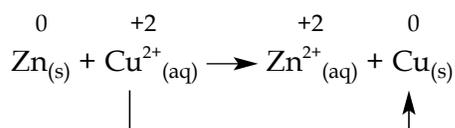


Step 2: Check which reactant is losing electrons. This will be the oxidized substance.



Zn is losing 2 electrons to form  $\text{Zn}^{2+}$ . Therefore, Zn is oxidized. Zn also is the reducing agent, as it supplies electrons to the reactant getting reduced.

Step 3: Check which reactant is gaining electrons. This will be the reduced substance.



$\text{Cu}^{2+}$  is gaining 2 electrons to form Cu. Therefore,  $\text{Cu}^{2+}$  is reduced.  $\text{Cu}^{2+}$  also is the oxidizing agent, as it takes away electrons from the reactant being oxidized.

Step 4: Check whether a reduction and an oxidation occur. If both processes occur, then it is a redox reaction.

Steps 2 and 3 confirm that this is a redox reaction.

**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

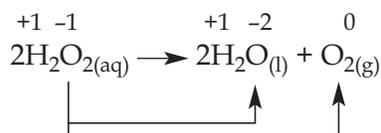
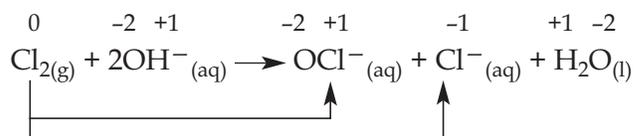
**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

**Teacher Background**

A special type of redox reaction is one in which two elements in the same compound change oxidation numbers. This is sometimes called a *disproportionation reaction*. Two such examples are provided below.

*Examples:*


**Simulation**

Have students view an online simulation of a redox reaction.

*Sample Website:*

Chemical Education Research Group, Iowa State University. "Chemistry Experiment Simulations and Conceptual Computer Animations." *Chemical Education*. <<http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/simDownload/index4.html>> (18 Jan. 2012).

In the Electrochemistry section, download and unzip the following simulation:

■ Reactions of Metals and Metal Ions Experiment

This simulation illustrates a redox reaction at the molecular level when a metal is immersed in aqueous ionic solution. Students can predict what will occur prior to placing the metal in the solution.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

## SPECIFIC LEARNING OUTCOME

C12-1-10: Identify reactions as redox or non-redox.

Include: oxidizing agent, reducing agent, oxidized substance, and reduced substance

(continued)

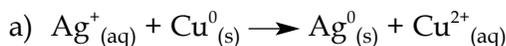
## SUGGESTIONS FOR ASSESSMENT

### Paper-and-Pencil Tasks

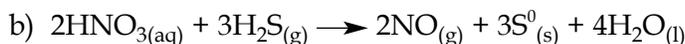
- Have students solve problems dealing with the identification of redox and non-redox reactions.
- Students should also be able to identify the oxidizing agent, reducing agent, oxidized substance, and reduced substance in a redox reaction. Use the convention that the “substance” is usually an atomic species, and therefore will not use an ionic notation (e.g., N, as opposed to  $N^{+5}$ ). Teachers may choose alternative ways of describing the substance oxidized or reduced, but consistency throughout is important.

*Examples:*

For each of the following reactions, students could determine the substance being oxidized, the substance being reduced, the oxidizing agent, and the reducing agent.



- Which substance is being oxidized?  $Cu^0_{(s)}$
- Which substance is being reduced?  $Ag^+_{(aq)}$
- What is the oxidizing agent?  $Ag^+_{(aq)}$
- What is the reducing agent?  $Cu^0_{(s)}$



- Which substance is being oxidized? S
- Which substance is being reduced? N
- What is the oxidizing agent?  $HNO_{3(aq)}$
- What is the reducing agent?  $H_2S_{(g)}$

- Students could create an analogy that shows each of the following terms: *oxidation*, *reduction*, *oxidizing agent*, and *reducing agent* (Dingrando, et al., *Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* 636).

### SKILLS AND ATTITUDES OUTCOMES

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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### Three-Point Approach for Words and Concepts

Ask students to use the Three-Point Approach to describe the terms *oxidizing agent*, *reducing agent*, the *substance oxidized*, and the *substance reduced* (see SYSTH 10.22).

### Journal Writing

At least two mnemonic devices are often used to assist students with remembering the definition of oxidation and reduction:

- OIL RIG – oxidation is losing and reduction is gaining
- LEO GER – losing electrons oxidation and gaining electrons reduction

Students could have a creative time either artistically or with words to illustrate these mnemonic devices. For example, students could draw a cartoon or a short comic strip of an atom losing an electron to another atom (Dingrando, et al., *Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* 638).

### LEARNING RESOURCES LINKS

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*Chemistry* (Chang 127)

*Chemistry* (Zumdahl and Zumdahl 169)

*Chemistry: The Molecular Nature of Matter and Change* (Silberberg 151)

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom 559)

*Glencoe Chemistry: Matter and Change* (Dingrando, et al.)

Section 20.1: Oxidation and Reduction, 635

*Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* (Dingrando, et al. 636, 638)

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al. 726)

*McGraw-Hill Ryerson Inquiry into Chemistry* (Chastko, et al. 436)

*Nelson Chemistry 12, Ontario Edition* (van Kessel, et al. 674)

*Nelson Chemistry 12: College Preparation, Ontario Edition* (Davies, et al. 382)

*Prentice Hall Chemistry* (Wilbraham, et al.)

Section 20.1: The Meaning of Oxidation and Reduction, 631

### Investigation

*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom)

ChemLab: Copper Atoms and Ions: Oxidation and Reduction, 560

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**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOME**

**C12-1-10:** Identify reactions as redox or non-redox.

Include: oxidizing agent, reducing agent, oxidized substance, and reduced substance

(continued)

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**Website**

Chemical Education Research Group, Iowa State University. "Chemistry Experiment Simulations and Conceptual Computer Animations."

*Chemical Education*. <<http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/simDownload/index4.html>> (18 Jan. 2012).

Simulation: Reactions of Metals and Metal Ions Experiment

**Selecting Learning Resources**

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**SKILLS AND ATTITUDES OUTCOMES**

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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**NOTES**

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-11:** Balance oxidation-reduction reactions using redox methods.  
Include: acidic and basic solutions

**(3 hours)**

SLO: C12-1-11

**SUGGESTIONS FOR INSTRUCTION****Entry-Level Knowledge**

Students learned about the conservation of atoms in Grade 10 Science (S2-2-06), and about the conservation of atoms and mass during a chemical reaction in Grade 11 Chemistry (C11-3-12 and C11-3-13).

**Assessing Prior Knowledge**

Check for students' understanding of prior knowledge and review concepts as necessary.

**TEACHER NOTES**

There are two basic methods for balancing oxidation-reduction reactions. The method that deals with oxidation numbers is addressed here in Topic 1 as an introduction to redox reaction. The other more efficient method involving half-cell reactions is addressed in Topic 6, where oxidation potentials and the electromotive series can be discussed more comprehensively.

**Note:**

Because of the links between oxidation-reduction and electrochemistry, teachers may consider teaching Topic 6: Electrochemistry following learning outcome C12-1-11.

Generally, if the reaction is written in the molecular form, as in the first example that follows, then the acid or base will already be included in the reaction. In the case of ionic aqueous reactions,  $H^+$  ions or  $OH^-$  ions would need to be added to the appropriate side to balance both ion charge and elemental species. The following examples will clearly illustrate this.

**Oxidation-Number Change Method**

Use the steps illustrated in the following examples to balance a redox reaction using the oxidation-number change method. With this method, a redox equation is balanced by comparing the increases and decreases in oxidation numbers (i.e., electrons lost and gained).

**General Learning Outcome Connections**

**GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.



**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-11:** Balance oxidation-reduction reactions using redox methods.  
Include: acidic and basic solutions

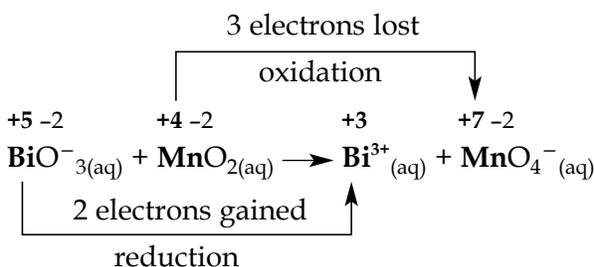
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*Example 2: Acidic Solution*

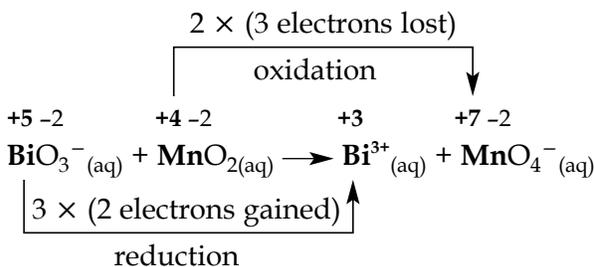
Balance the following aqueous oxidation-reduction reaction that occurs in an *acidic solution*.



- Assign oxidation numbers to all the atoms in the reaction. Write the numbers above the appropriate atoms and show electrons lost and gained.



- Balance electrons lost and gained using appropriate coefficients.

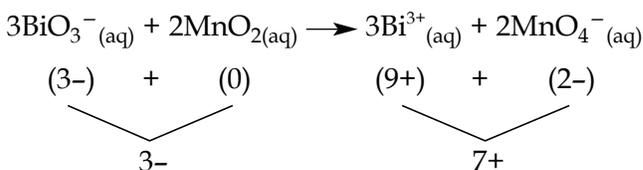


- Write the coefficients in front of the appropriate species.



- Add up the ion charges and balance with  $\text{H}^+$ , since the reaction occurs in an *acidic solution*.

Total the charges on both sides separately.



**SKILLS AND ATTITUDES OUTCOMES**

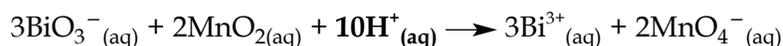
**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

Therefore,  $10\text{H}^+$  ions need to be added to the left side of the reaction to balance the ion charge.

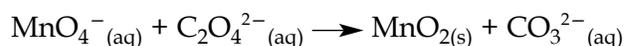


5. Water is now added to the opposite side to balance H and O atoms.

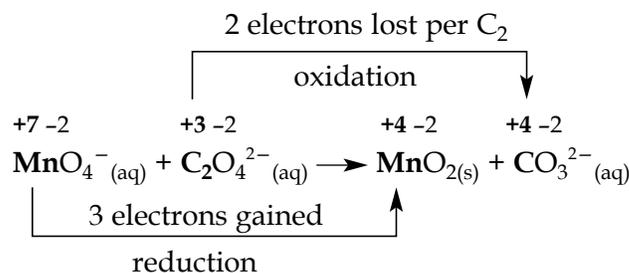


*Example 3: Basic Solution*

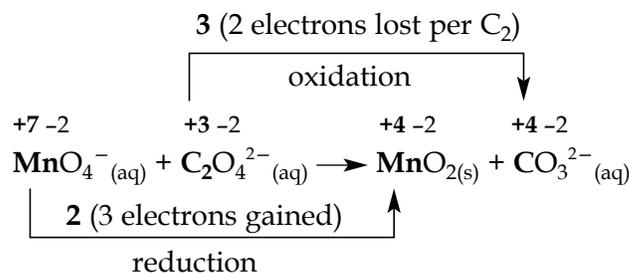
Balance the following aqueous oxidation-reduction reaction that occurs in a *basic solution*.



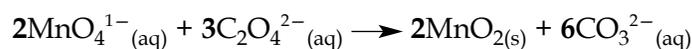
1. Assign oxidation numbers to all the atoms in the reaction. Write the numbers above the appropriate atoms and show electrons lost and gained.



2. Balance electrons lost and gained using appropriate coefficients.



3. Write the coefficients in front of the appropriate species.



Note that  $6\text{CO}_3^{2-}$  is required to balance the C atoms in  $3\text{C}_2\text{O}_4^{2-}$ .

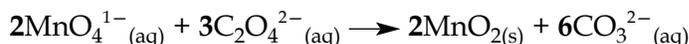
**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

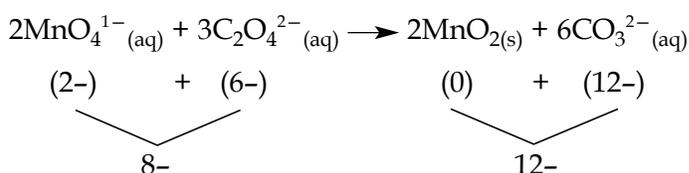
**C12-1-11:** Balance oxidation-reduction reactions using redox methods.  
Include: acidic and basic solutions

(continued)

4. Add up the ion charges and balance with  $\text{OH}^-$ , since the reaction occurs in a basic solution.



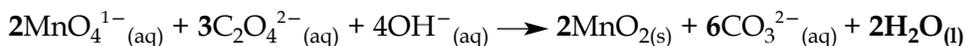
Total the charges on both sides separately.



Therefore,  $4\text{OH}^-$  ions need to be added to the left side of the reaction to balance the ion charge.

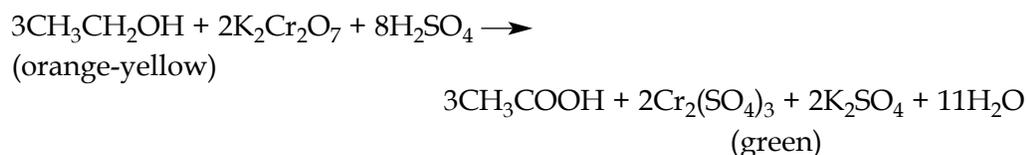


5. Water is now added to the opposite side to balance H and O atoms.



**Demonstration**

A breathalyzer test works on a redox reaction given below. If students like a challenge, ask them to balance this reaction.



Historically, before laser spectrophotometry became prevalent in roadside breath analysis equipment, the driver being assessed provided a breath sample to a solution of potassium dichromate that was an orange-green colour. As the ethanol (if present in the sample) reacted with the acid, the solution would become increasingly green. The degree of change was then measured by a simple spectrophotometer. As the wavelength of emitted light shifted to green, it indicated a larger amount of dissolved alcohol in the breath. These traditional reagents are readily available in most school laboratories.

Build a simple breathalyzer and bubble denatured ethanol into it to test the change in colour. Generic mouthwash is a safe source to simulate alcohol on the breath.

What would happen if methanol or isopropyl alcohol were used instead of ethanol?

### SKILLS AND ATTITUDES OUTCOMES

**C12-0-U1:** Use appropriate strategies and skills to develop an understanding of chemical concepts.

*Examples: analogies, concept frames, concept maps, manipulatives, particulate representations, role-plays, simulations, sort-and-predict frames, word cycles . . .*

**C12-0-U2:** Demonstrate an understanding of chemical concepts.

*Examples: use accurate scientific vocabulary, explain concepts to others, compare and contrast concepts, apply knowledge to new situations and/or contexts, create analogies, use manipulatives . . .*

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## SUGGESTIONS FOR ASSESSMENT

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### Paper-and-Pencil Task

Have students balance redox equations using process notes (see *SYSTH* 13.14).

### Journal Writing

Students may wish to write an account of the technology that goes into the functioning and use of a traditional breathalyzer.

## LEARNING RESOURCES LINKS

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*Glencoe Chemistry: Concepts and Applications* (Phillips, Strozak, and Wistrom)  
Breathalyzer Test, 569

*Glencoe Chemistry: Matter and Change* (Dingrando, et al.)  
Section 20.2: Balancing Redox Equations, 644  
The Oxidation-Number Method, 644  
Section 20.3: Half-Reactions, 650

*McGraw-Hill Ryerson Chemistry, Combined Atlantic Edition* (Mustoe, et al.)  
18.2: Oxidation Numbers, 721  
18.3: The Half-Reaction Method for Balancing Equations, 730

*Prentice Hall Chemistry* (Wilbraham, et al.)  
Section 20.3: Balancing Redox Equations, 645

#### Selecting Learning Resources

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**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

**C12-1-12:** Research practical applications of redox reactions.

*Examples: rocket fuels, fireworks, household bleach, photography, metal recovery from ores, steelmaking, aluminum recycling, fuel cells, batteries, tarnish removal, fruit clocks, forensic blood detection using luminol, chemiluminescence/bioluminescence, electrolytic cleaning, electrodeposition, photochemical etching, antioxidants/preservatives . . .*

**(4 hours)**

SLO: C12-1-12

**SUGGESTIONS FOR INSTRUCTION****TEACHER NOTES**

In addressing learning outcome C12-1-12, ask students to choose a research topic early in the school year so that they can research information and ideas on the practical applications of redox reactions over an extended period of time. Group presentations would be done during the study of Topic 6: Electrochemistry at the end of the course. In their research, students could focus their attention on

- the redox reaction taking place
- the effect of the process on the environment
- the energy consumption involved

Encourage students to investigate and perform demonstrations to support their oral presentations on their selected research topics.

**General Learning Outcome Connections**

- GLO A3:** Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.
- GLO A4:** Identify and appreciate contributions made by women and men from many societies and cultural backgrounds that have increased our understanding of the world and brought about technological innovations.
- GLO A5:** Recognize that science and technology interact with and advance one another.
- GLO B1:** Describe scientific and technological developments—past and present—and appreciate their impact on individuals, societies, and the environment, both locally and globally.
- GLO B2:** Recognize that scientific and technological endeavours have been and continue to be influenced by human needs and the societal context of the time.
- GLO B4:** Demonstrate knowledge of and personal consideration for a range of possible science- and technology-related interests, hobbies, and careers.
- GLO C2:** Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
- GLO C4:** Demonstrate appropriate critical thinking and decision-making skills when choosing a course of action based on scientific and technological information.
- GLO C5:** Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.
- GLO C6:** Employ effective communication skills and use information technology to gather and share scientific and technological ideas and data.
- GLO C7:** Work cooperatively and value the ideas and contributions of others while carrying out scientific and technological activities.
- GLO D3:** Understand the properties and structures of matter, as well as various common manifestations and applications of the actions and interactions of matter.

**SKILLS AND ATTITUDES OUTCOMES**

- C12-0-R1:** Synthesize information obtained from a variety of sources.  
Include: print and electronic sources, specialists, and other resource people
- C12-0-R5:** Communicate information in a variety of forms appropriate to the audience, purpose, and content.
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**Practical Applications of Redox Reactions: Research Topics**

Have groups of students research practical applications of redox reactions and prepare a written report and an oral presentation on their findings. The following information serves as an introduction to the various applications of redox reactions cited as examples in learning outcome C12-1-12. Choose examples that relate to student and teacher interest and experience. This material can be supplemented by additional research using the usual resources (e.g., Internet, texts, encyclopedias, journals, experts). Ideally, students would provide information from their own sphere of experience. For a sample assignment, see Appendix 1.12A: Practical Applications of Redox Reactions (Research Report and Presentation).

**■ Rocket Fuels**

Each solid rocket booster of the space shuttle, used during the first two minutes of a launch, contains 495 000 kg of an explosive mixture of ammonium perchlorate and aluminum:

**■ Fireworks**

The heat and thrust of a fireworks shell are produced by exothermic redox reactions. A typical fireworks composition consists of an oxidizer (such as potassium perchlorate), a fuel (such as aluminum or magnesium), a binder, and some chemicals for the special effects of colour, sparks, and smoke. For example, green fireworks are made by adding a barium compound, and gold sparks are produced by adding iron filings or charcoal.

**Topic 1:**  
**Reactions in**  
**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

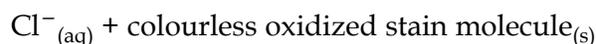
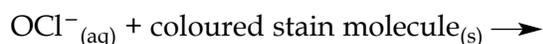
**C12-1-12:** Research practical applications of redox reactions.

*Examples: rocket fuels, fireworks, household bleach, photography, metal recovery from ores, steelmaking, aluminum recycling, fuel cells, batteries, tarnish removal, fruit clocks, forensic blood detection using luminol, chemiluminescence/bioluminescence, electrolytic cleaning, electrodeposition, photochemical etching, antioxidants/preservatives . . .*

(continued)

■ **Household Bleach**

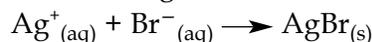
Through the process of oxidation, unwanted colours (stains) are removed (oxidized) by bleach. Colour is caused by the movement of electrons between different energy levels of the atoms of the material.



■ **Photography**

There are three different redox reactions in black-and-white photography:

1. The film negative is an emulsion of silver bromide:

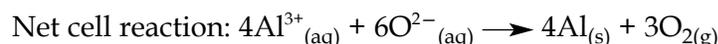


2. The film is processed, and the remaining  $\text{Ag}^+_{(\text{aq})}$  is converted to free silver by a reducing agent. The unreacted  $\text{AgBr}$  is removed by an appropriate solution process. This step produces the negative.

3. The negative is then printed onto photographic paper.

■ **Metal Recovery from Ores**

Aluminum metal is obtained by electrolysis of aluminum oxide (refined bauxite), using the Hall-Héroult process.



This process uses huge amounts of electric energy. Recycling of aluminum is a lot more cost-effective than the processing of bauxite.

Copper, silver, gold, platinum, and palladium are the only transition metals that are unreactive enough to be found in nature uncombined with other elements.

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**■ Steelmaking**

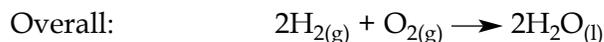
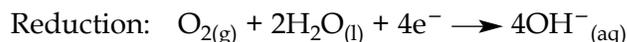
One aspect of steelmaking is the basic oxygen process used to purify iron (the most common method used). Scrap steel is mixed with molten iron in a blast furnace. Oxygen is introduced (injected) to oxidize the impurities.

**■ Aluminum Recycling**

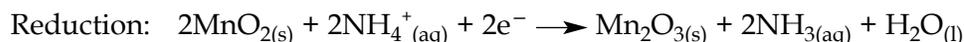
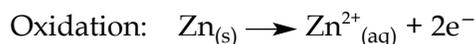
All aluminum products can be recycled after use. Scrap aluminum is generally taken by road to the recycling plant, where it is checked and sorted to determine composition and value. If the scrap is of unknown quality, the aluminum will first be passed through some large magnets to remove any ferrous metal. Depending upon the type of contamination present, some scrap must be further processed. Beverage cans, for example, must have their lacquer removed prior to aluminum recovery.

**■ Fuel Cells**

The most common fuel cell is the hydrogen-oxygen fuel cell used in the space shuttle. Some automotive manufacturers are now using fuel cells as a means of power.


**■ Batteries**

The flow of electrons in a battery is possible because zinc is oxidized in the battery, and manganese dioxide ( $\text{MnO}_2$ ) is reduced. The following chemical reactions occur:



**Topic 1:**  
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**Aqueous Solutions**

**SPECIFIC LEARNING OUTCOME**

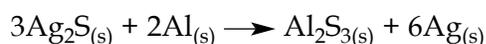
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(continued)

■ **Tarnish Removal**

Silver tarnish ( $\text{Ag}_2\text{S}$ ) is formed by a redox reaction involving environmental sulphides. To remove the tarnish, aluminum reacts in the following way:



■ **Fruit Clocks**

Inserting two electrodes of differing metals into a piece of fruit (such as a lemon) and connecting them with wires will cause an electric current to flow to a basic liquid-crystal display clock:



■ **Forensic Blood Detection Using Luminol**

Criminalists spray a luminol mixture wherever they think blood might be found. If hemoglobin and the luminol mixture come in contact, the iron in the hemoglobin accelerates a reaction between the hydrogen peroxide and the luminol. In this oxidation reaction, the luminol loses nitrogen and hydrogen atoms and gains oxygen atoms, resulting in a compound called 3-aminophthalate. The reaction leaves the 3-aminophthalate in an energized state – the electrons in the oxygen atoms are boosted to higher orbitals. The electrons quickly fall back to a lower energy level, emitting the extra energy as a light photon. With iron accelerating the process, the light is bright enough to see in a dark room.

■ **Chemiluminescence/Bioluminescence**

Most *chemiluminescence* methods involve only a few chemical components to generate light. Luminol chemiluminescence and peroxyoxalate chemiluminescence are both used in bioanalytical methods. In each system, a “fuel” is chemically oxidized to produce an excited-state product. In many luminol methods, it is this excited product that emits the light for the signal. In peroxyoxalate chemiluminescence, the initial excited-state product does not emit light at all; instead, it reacts with another compound, often a compound also viable as a fluorescent dye, and it is this fluorophore that becomes excited and emits light.

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*Bioluminescence* is light produced by a chemical reaction within an organism. At least two chemicals are required. The one that produces the light is generically called a *luciferin* and the one that drives or catalyzes the reaction is called a *luciferase*.

**■ Electrolytic Cleaning**

Electrolysis can be used to clean metal objects, as explained by Dingrando, et al:

Coatings of salts from the seawater on metal objects are removed by an electrochemical process. A voltaic cell is set up with a cathode that is the object itself and a stainless steel anode in a basic solution. Chloride ions are removed when the electric current is turned on.

In another process, bacteria convert sulfate ions to hydrogen sulfide gas and cause silver coins and bars to become coated with silver sulfide after long periods of time at the bottom of the ocean. In an electrolytic cell, the silver in silver sulfide can be reduced to silver metal and reclaimed. (*Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition 684*)

**■ Electrodeposition**

The process used in electroplating is called *electrodeposition* (e.g., making CDs). The item to be coated is placed into a solution of one or more metal salts. The item is connected to an electrical circuit, forming the cathode (negative) of the circuit, while the anode (positive) is typically made of the metal to be plated on the item. When an electrical current is passed through the circuit, metal ions in the solution are attracted to the item. The result is a layer of metal on the item. Considerable skill is required to produce an evenly coated finished product. This process is analogous to a galvanic cell acting in reverse.

**Topic 1:  
Reactions in  
Aqueous Solutions**

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**SPECIFIC LEARNING OUTCOME****C12-1-12:** Research practical applications of redox reactions.

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*(continued)*

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**■ Photochemical Etching**

In the photochemical etching process, “ultraviolet light is used to transfer a pattern onto a piece of metal. Then chemicals are applied to remove certain areas in the pattern, creating an intricate design on the metal” (Dingrando, et al., *Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* 641).

**■ Antioxidants/Preservatives**

Oxidation can cause the decay of food and other organic material (e.g., human skin). Antioxidants help reduce the decay of some essential amino acids and the loss of some vitamins. Antioxidants, such as vitamin C, vitamin E, BHT (butylated hydroxytoluene), BHA (butylated hydroxyanisole), sulphites, and sulphur dioxide, react more readily with oxygen than the food does. This keeps the food from spoiling.

**■ Heart Pacemakers**

Engineered in Canada by John Hopps in the 1940s, the pacemaker sends electrical impulses to the heart muscle to correct heartbeat irregularities. The pacemaker obtains its energy from a battery that lasts seven years.

**■ Corrosion Prevention**

Paint, or another protective coating, can protect steel structures from corrosion. Sacrificial anodes of magnesium, zinc, or other active metals are also used to prevent corrosion.

**SUGGESTIONS FOR ASSESSMENT**

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**Research**

It may be beneficial to have students begin their research on the applications of redox chemistry now, and present or display their projects later during the study of Topic 6: Electrochemistry. For assessment suggestions, refer to Appendix 1.12B: Practical Applications of Redox Reactions (Sample Checklist and Assessment Rubric).

Students may wish to use a variety of presentation modes: models, posters, computer-generated materials, animation, video, murals, and so on.

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### LEARNING RESOURCES LINKS

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*Glencoe Chemistry: Matter and Change* (Dingrando, et al.)  
Chapter 21: Electrochemistry, 662

*Glencoe Chemistry: Matter and Change, Teacher Wraparound Edition* (Dingrando, et al. 641, 684)

*Prentice Hall Chemistry* (Wilbraham, et al.)  
Chapter 21: Electrochemistry, 662

#### Appendices

Appendix 1.12A: Practical Applications of Redox Reactions (Research Report and Presentation)

Appendix 1.12B: Practical Applications of Redox Reactions (Sample Checklist and Assessment Rubric)

#### Selecting Learning Resources

For additional information on selecting learning resources for Grade 11 and Grade 12 Chemistry, see the Manitoba Education website at <[www.edu.gov.mb.ca/k12/learnres/bibliographies.html](http://www.edu.gov.mb.ca/k12/learnres/bibliographies.html)>.

