Adult Basic Education

Science

# Chemistry 3102B

# Equilibrium/Acids and Bases

## Curriculum Guide

**Prerequisite:** Chemistry 3102A

**Credit Value:** 1

**Chemistry Concentration**

Chemistry 1102
Chemistry 2102A
Chemistry 2102B
Chemistry 2102C
Chemistry 3102A
**Chemistry 3102B**
Chemistry 3102C

## Table of Contents

## To the Instructor

# I. Introduction to Course 3102B

Chemistry 3102B introduces students to the concept of equilibrium. In chemistry, equilibrium is not what it appears to be at the macroscopic level. Chemical equilibria involve molecules changing back and forth between products and reactants. Up to now, chemical systems have been treated simplistically as reactants forming products. This is often not the case and in fact there are often both reactants and products present at the same time.

Students met the concepts of acids and bases in Chemistry 1106. They will meet them again in this course, but they will find that acid and base chemistry involves an equilibrium system and by understanding this system, they will have a much better understanding of acids, bases and their properties.

If students have not completed study of logarithms in their mathematics courses, they will need to do so before progressing to the last unit of this course.

Chemistry 3102B, along with Chemistry 3102A and C, are equivalent to Chemistry 3202 in the current high school program. **Chemistry 3102A is a pre-requisite to this course**.

# II. Curriculum Guides

Each new ABE Science course has a Curriculum Guide for the instructor and a Study Guide for the student. The Curriculum Guide includes the specific curriculum outcomes for the course. Suggestions for teaching, learning, and assessment are provided to support student achievement of the outcomes. Each course is divided into units. Each unit comprises a **two-page layout of four columns** as illustrated in the figure below. In some cases the four-column spread continues to the next two-page layout.

## To the Instructor

**Curriculum Guide Organization:**
**The Two-Page, Four-Column Spread**

| **Unit Number - Unit Title** | | **Unit Number - Unit Title** | |
|---|---|---|---|
| **Outcomes**<br><br>Specific curriculum outcomes for the unit. | **Notes for Teaching and Learning**<br><br>Suggested activities, elaboration of outcomes, and background information. | **Suggestions for Assessment**<br><br>Suggestions for assessing students' achievement of outcomes. | **Resources**<br><br>Authorized and recommended resources that address outcomes. |

## III. Study Guides

The Study Guide provides the student with the name of the text(s) required for the course and specifies the sections and pages that the student will need to refer to in order to complete the required work for the course. It guides the student through the course by assigning relevant reading and providing questions and/or assigning questions from the text or some other resource. Sometimes it also provides important points for students to note. (See the *To the Student* section of the Study Guide for a more detailed explanation of the use of the Study Guides.) The Study Guides are designed to give students some degree of independence in their work. Instructors should note, however, that there is much material in the Curriculum Guides in the *Notes for Teaching and Learning* and *Suggestions for Assessment* columns that is not included in the Study Guide and instructors will need to review this information and decide how to include it.

## IV. Resources

### *Essential Resources*

*Chemistry: Mustoe, Jansen, et al; McGraw-Hill Ryerson, 2004.*
*McGraw-Hill Chemistry Teacher's Resource (including CD-ROM)*

### *Recommended Resources*

*Chemistry 3202 Curriculum Guide*:
http://www.ed.gov.nl.ca/edu/sp/chem_3202.htm

*Chemistry 11/12 Computerized Assessment Banks.*

*Textbook website:*
*http://www.mcgrawhill.ca/school/booksites/chemistry/index.php*

### *Other Resources*

*Center for Distance Learning and Innovation*: http://www.cdli.ca/

*Access Excellence Resource Center:*
http://www.accessexcellence.org/RC/chemistry.html

Virtual Chemistry: http://neon.chem.ox.ac.uk/vrchemistry/

## V. Recommended Evaluation

| | |
|---|---|
| Written Notes | 10% |
| Labs/Assignments | 20% |
| Test(s) | 20% |
| Final Exam *(entire course)* | 50% |
| | 100% |

**The overall pass mark for the course is 50%**

# Equilibrium/Acids and Bases

## Unit 1 - Dynamic Equilibrium

| Outcomes | Notes for Teaching and Learning |
|---|---|
| 1.1 Define the concept of dynamic equilibrium as it pertains to reversible chemical reactions. | Instructors should introduce the topic of equilibrium by discussing with student(s) the examples on pages 489-490 of the text. |
| 1.1.1 State the criteria that apply to a system at equilibrium: closed system with constant temperature, constancy of macroscopic properties, evidence of reversibility, and equal rates of forward and reverse processes. | Instructors should make sure that students realize that a reaction at equilibrium may appear to have stopped, but, at the molecular level, chemical reactions are still occurring in both the forward and reverse directions at the same rate.<br><br>See the Teaching Strategies on pages 194 - 195 in the Teacher's Resource for some suggestions for helping students understand the concept of equilibrium. |
| 1.2 Define the concept of equilibrium constant expression as it pertains to chemical systems. | The textbook uses $K_c$ to indicate that K is expressed in terms of molar concentration. |
| 1.2.1 Write the equilibrium constant expression, K, for chemical systems. | Instructors should reinforce that the liquids and solids are not included in the K expression, and that the final value of K has no units. |
| 1.2.2 Recognize that solids and liquids are not included in the equilibrium expression, K. | BLM 13-1 can be used to visually illustrate the macroscopic concepts of a system in equilibrium and to reinforce the conditions necessary for a system in equilibrium. |
| 1.2.3 Recognize that the constant, K, will vary with temperature. | |
| 1.2.4 Calculate equilibrium constants for simple chemical systems when concentrations at equilibrium are known. | |

## Unit 1 - Dynamic Equilibrium

### Suggestions for Assessment

Possible questions that could be used for assessment:

What happens to the value of $K_c$ if the concentration of a reactant changes?

Given reactant and product concentrations, ask students to calculate the value of $K_c$.

Ask students to write $K_c$ expressions for Problems 11 to 15 on page 508 - 509.

Students may check the answers to the Practice Problems assigned from Chapter 13 by referring to page 537 of the text. Instructors should make sure that students are using the correct procedures to arrive at these answers.

Instructors could assign questions from the Section Review and/or Chapter Review. Also, there are "Additional Practice Problems" on the Teacher's Resource CD-ROM.

The CDLI (Center for Distance Learning and Innovation) website was developed for distance delivery of selected high school courses. It contains lots of materials that could be useful in the delivery of Adult Basic Education courses.

Note: You will need a username and password to enter the CDLI site.

### Resources

MGH Chemistry: pages 488-493; 536

Teacher's Resource for MGH Chemistry (including CD-Rom).

BLM13-1, "Illustrating a Chemical System in Equilibrium".

Website for the text: http://www.mcgrawhill.ca/school/booksites/chemistry/index.php

Department of Education website: http://www.ed.gov.nl.ca/edu/science_ref/chem3202.htm

The centre for distance learning and innovation website: http://www.cdli.ca/

## Unit 1 - Dynamic Equilibrium

### Outcomes

1.2.5 Predict whether reactants or products or neither are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant.

### Notes for Teaching and Learning

See the Teaching Strategies for Section 13.2 on page 197 in the Teacher's Resource for some suggestions for helping students understand the equilibrium constant.

If K is much greater than 1, products are favored; if K is much less than 1, reactants are favored. Instructors should note that this is a qualitative interpretation of K.

Remind students that $K_c$ is a ratio of the concentrations of products to reactants. Ensure that they are aware that placing molecular formulas in square brackets signifies the concentration of the molecule.

## Unit 1 - Dynamic Equilibrium

### Suggestions for Assessment

Refer to the values of $K_c$ in Problems 8 to 10 on page 535, ask students about the *relative* quantities of reactants and products.

Instructors should check students' answers to all questions assigned in the Study Guide.

### Resources

MGH Chemistry: page 511; 535

## Unit 2 - Predicting the Direction of a Reaction

### Outcomes

2.1 Explain how different factors affect chemical equilibrium.

2.1.1 State Le Châtelier's Principle.

2.1.2 Use Le Châtelier's Principle to predict, qualitatively, shifts in equilibrium caused by changes in temperature, pressure, volume or concentration.

2.1.3 Explain why the addition of a catalyst and varying surface area of a reactant or product do not cause the equilibrium to shift, yet both factors do have an effect on the time it takes for a system to reach equilibrium.

### Notes for Teaching and Learning

Le Châtelier's Principle could be presented as a summary of how equilibria respond to changes in the temperature, pressure and concentration (of one reactant or product). Students will learn how to apply this principle.

Various industrial links to Le Châtelier's Principle may be made, the most famous being the Haber Process in the production of ammonia. This is described on page 530 to 532 of the text.

## Unit 2 - Predicting the Direction of a Reaction

### Suggestions for Assessment

Instructors should assess students' answers to all questions assigned in the Study Guide.

Problems 5 to 7 on page 535 of text can be used for assessment.

This is the end of the part of the course on equilibrium. Instructors may give a test that could be used as part of the evaluation for the course.

BLM 13-3, Chapter 13 Test, can be used to evaluate understanding of equilibrium concepts. Instructors should choose the questions that test the skills and knowledge that students should have acquired.

### Resources

Teacher's Resource CD-ROM,
BLM 13-3, "Chapter 13 Test".

MGH Chemistry: pages 517-532.

Chemistry 11/12 Computerized Assessment Banks.

## Unit 3 - Properties of Acids and Bases

### Outcomes

3.1 Describe and apply classification systems and nomenclature used in acids and bases.

> 3.1.1 Define acids and bases operationally in terms of their taste, reactions with each other, solution conductivity, and effect on indicators.
>
> 3.1.2 Identify that an operational definition can only classify a substance as acidic or basic, but is not useful in determining chemical formulas.

3.2 Describe various acid-base definitions up to the Brønsted-Lowry definition, including the limitations of these definitions.

> 3.2.1 Define and identify Arrhenius, modern Arrhenius and Brønsted-Lowry acids and bases.

### Notes for Teaching and Learning

Students should be familiar with moles and stoichiometric calculations. They should also be familiar with the nature of solutions and expressing solution concentration from previous Chemistry courses. Instructors should check their knowledge in these areas and review, if necessary, before they begin this unit.

Investigation 14-A "Observing Properties of Acids and Bases" is a **Core Lab** for this course.

Students should define acids and bases operationally in terms of, taste, neutralization reactions with each other, conductivity, and effect on indicators. Instructors could also point out that their effect on pH and reactions with metals could also be included in operational definitions.

Students should explain how some substances helped revise Arrhenius' theoretical definition of acids. For example, Arrhenius' theory cannot explain why $NH_3$ is a base. This will be the underlying theme as the various theoretical definitions of acids are studied.

The development of the acid-base theories up to Brønsted-Lowry could be traced to show how knowledge and thinking changed to explain new observations.

Full solutions for Practice Problems are in the *Solutions Manual* on the *Teacher's Resource CD-Rom.*

## Unit 3 - Properties of Acids and Bases

### Suggestions for Assessment

Instructors may find that the sites listed in Teacher's Resource are good sources to find extra practice. There are many other websites and books that can be used.

Using appropriate tests, students could classify the following as an acid, a base, or neutral (neither acidic nor basic):

- sodium carbonate
- hydrochloric acid
- sulfuric acid
- potassium hydroxide
- calcium hydroxide
- ammonia
- sugar

Problems 1 to 6 on page 579, could be used for further assessment and reinforcement.

Students are expected to submit a lab report which will be marked and the mark used as part of the evaluation for the course. See the Teacher's Resource for answers to all the lab questions.

### Resources

MGH Chemistry, pages 542-558; 579

***Core Lab:***
*Investigation 14-A, "Observing Properties of Acids and Bases", pages 546-547.*

## Unit 3 - Properties of Acids and Bases

### Outcomes

3.2.2 Write representative chemical equations for species acting as an acid or a base.

3.2.3 Identify the limitations of the operational, Arrhenius and modern Arrhenius definitions of acids and bases

### Notes for Teaching and Learning

Students should define, identify, and write ionization equations for the behaviour of Arrhenius, modern Arrhenius and Brønsted-Lowry **bases** as shown by:

**Arrhenius**

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

**Modern Arrhenius**

$NH_{3(l)} + H_2O_{(l)} \rightarrow NH_4OH_{(aq)}$ $NH_4{+}_{(aq)} + OH^{-}_{(aq)}$

**Brønsted-Lowry**

$HPO_4{}^{2-}_{(l)} + CH_3COOH_{(aq)} \rightarrow CHCOO^{-}_{(aq)} + H^2PO^{4-}_{(aq)}$

**Note:** The modern Arrhenius theory would not be used for an ionic hydroxide base such as sodium hydroxide, since the result would give the same equation as the Arrhenius theory.

Students should define, identify, and write ionization equations for the behaviour of Arrhenius, modern Arrhenius and Brønsted-Lowry **acids** as shown by:

**Arrhenius:**

$HBr_{(aq)} \rightarrow H^{+}_{(aq)} + Br^{-}_{(aq)}$

**Modern Arrhenius:**

$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^{+}_{(aq)} + Cl^{-}_{(aq)}$

**Brønsted-Lowry:**

$HNO_{3\ (aq)} + HCO^{-}_{3\ (aq)} \rightarrow H_2CO_{3\ (aq)} + NO_3{}^{-}_{(aq)}$

## Unit 3 - Properties of Acids and Bases

### Suggestions for Assessment

Students could write an equation for the dissociation of ionic compounds such as, $Mg(OH)_{2(s)}$.

Students could write an equation for the ionization of compounds such as, $HClO_{3(aq)}$.

Instructors should assess students' answers to all questions from the Study Guide.

Students may check the answers to the Practice Problems assigned from Chapter 14 by referring to page 581 of the text.

Instructors could assign questions from the Section Review and/or Chapter Review. Also, there are "Additional Practice Problems" on the Teacher's Resource CD-ROM.

### Resources

MGH Chemistry: pages 542-558

## Outcomes

3.3 Identify new questions or problems that arise from what was learned.

3.3.1 Identify the Brønsted-Lowry acid, base, conjugate acid and conjugate base in a Brønsted Lowry acid-base equation.

3.3.2 Define and identify amphoteric substances as examples of species that can either accept or donate a proton.

3.3.3 Recognize the amphoteric nature of water.

## Notes for Teaching and Learning

Ionization of weak bases using equations (such as $NH_3$) should be included in discussion.

Students should interpret equations in Brønsted-Lowry terms and identify the acid and base species. Examples should include:

$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

$H_2SO_{4(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$

Instructors should recognize that some equations fall within the realm of both the modern Arrhenius and Brønsted-Lowry definitions. For example, the reaction of $NH_3$ in water (as shown in the modified Arrhenius example previously) may be interpreted as a Brønsted-Lowry equation given that the $NH_3$ accepts a proton from $H_2O$. The significance of the modified Arrhenius theory is the introduction of the hydronium ion, $H_3O^+$, for acids and the ability to explain non-hydroxide bases by means of a reaction of the basic species with water to produce $OH^-$. The utility of the Brønsted-Lowry definition is that water is not required in the definition of an acid or base.

Students should be able to identify conjugate acid-base pairs, as in:

$HPO_4^{2-}{}_{(aq)} + HCO_3^-{}_{(aq)} \quad H_2PO_4^-{}_{(aq)} + CO_3^{2-}{}_{(aq)}$

Base Acid Acid Base

In the above equation: $HPO_4^{2-}{}_{(aq)}$ and $H_2PO_4^-{}_{(aq)}$; and; $HCO_3^-{}_{(aq)}$ and $CO_3^{2-}{}_{(aq)}$ are conjugate acid-base pairs.

## Unit 3 - Properties of Acids and Bases

| Suggestions for Assessment | Resources |
|---|---|
| Students could summarize the differences between the theoretical definitions using a table or chart (on page 558 of the textbook). It is important that students understand why several theories of acids and bases developed and why scientists might not use the "latest" theory to explain phenomena. | MGH Chemistry, Chapter 14, Section 14.1 Review, page 559; Chapter 14 Review, page 579 - 581. |
| Students could complete questions 2-11 in the Section Review, page 559. | |
| Students could complete Study Quiz 1 for Chapter 14, on the textbook website. Self check answers are provided. | |
| Students could find the conjugate acid and conjugate base of:<br>( a ) $H_2O$<br>( b ) $HCO_3^-$<br>( c ) $HBO_3^{2-}$<br>( d ) $H_2PO_4^-$ | |
| BLM 14-1, "Illustrating the Properties of Acids and Bases", could be used to help students visualize the relationship between acids and their conjugate bases, and bases and their conjugate acids. | Teachers' Resource CD-ROM: BLM14-1, "Illustrating the Properties of Acids and Bases". |
| Instructors could assign questions from the Chapter 14 Review. | |

## Unit 4 - Strong and Weak Acids and Bases

### Outcomes

4.1 Explain the relative strength of an acid or a base in terms of percent ionization.

- 4.1.1 Define strong and weak acid.
- 4.1.2 Define strong and weak base.

4.2 Use a table of relative acid/base strengths.

- 4.2.1 Determine the relative acid strength of one species compared to another
- 4.2.2 Determine the relative base strength of one species compared to another.

4.3 Predict products of acid-base reactions

- 4.3.1 Predict whether reactants or products are favoured in an acid-base equilibrium, should an equilibrium result.

### Notes for Teaching and Learning

Reinforce the idea that acids do not contain free $H^+$ ions. These ions are produced from the dissociation of acid molecules in water to form an anion and the hydronium ion, $H_3O^+$.

Instructors should ensure that students have covered logarithms in Math 3104A before working on this unit. Appendix D, pages 841-842, of the text provides a lesson in *Logarithms and pH* that students should work through. The Mathematics instructor could be asked to help students with this topic.

Full solutions for Practice Problems are in the *Solutions Manual* on the *Teacher's Resource CD-Rom.*

Students will not cover "Dilution Calculations Involving Acids and Bases", pages 572 - 577.

## Unit 4 - Strong and Weak Acids and Bases

### Suggestions for Assessment

Students should complete questions 4.1 - 4.8 in the study guide to cover the material in Unit 4 of this course. Instructors should check their work when these questions are completed and assign additional practice and/or review as needed.

Using the relative acid strength table, ask students to explain why $H_2PO_4^-$ is labelled as shown below:

(i) $H_2PO_4^-$ + $HSO_3^-$
base

(ii) $H_2PO_4^-$ + $HBO_3^{2-}$
acid

Students could make predictions of which is the acid and which is the base in the following pairs:

(a) $HSO_4^-$ and $H_2PO_4^-$
(b) $HSO_3^-$ and $HOOCCOO^-$
(c) $HCO_3^-$ and $HS^-$

Students will need access to a diagram such as Figure 14.12 to do this.

### Resources

MGH Chemistry, pages 560 - 572.

Teacher's Resource for MGH Chemistry (including CD-Rom).

Website for the text: http://www.mcgrawhill.ca/school/booksites/chemistry/index.php

Department of Education website: http://www.ed.gov.nl.ca/edu/science_ref/chem3202.htm

The centre for distance learning and innovation website: http://www.cdli.ca/

## Unit 4 - Strong and Weak Acids and Bases

### Outcomes

4.4 Define pH and calculate it for an acid (or base) given the initial concentration and vice-versa.

4.4.1 Write the equilibrium for the self-ionization (auto-ionization) of water, and its corresponding equilibrium expression.

4.4.2 Define $K_w$.

4.4.3 Define the pH and pOH of systems in terms of the base 10 logarithms of the respective ions.

4.4.4 Define the relationship between $[H_3O^+]$, $[OH^-]$, pH, and pOH and convert between any two.

4.4.5 Calculate any of $[H_3O^+]$, $[OH^-]$, pH or pOH given either: the concentration of a strong monoprotic acid or the mass of a solid ionic hydroxide dissolved.

### Notes for Teaching and Learning

Instructors should make sure that students know how to use their calculators to find an antilog.

Note: Correction to Practice Problem 19 b. The exponent should be negative, $6.59 \times 10^{-10}$.

## Unit 4 - Strong and Weak Acids and Bases

### Suggestions for Assessment

Students could complete Study Quiz 3 for Chapter 14 on the textbook website. Self check answers are provided.

Students could be provided with questions and problems on any of the topics covered in this section. These questions and problems could be collected from a variety of reference books to which the instructor has access.

BLM14-2, “pH Calculations” can be used for additional practice.

Appropriate questions from BLM14-3, “Chapter 14 Test”, can be used to evaluate students’ understanding of the concepts covered from this Chapter.

A final comprehensive exam should be given for the course. The mark for this exam should comprise 50% of the final mark for the course.

### Resources

MGH Chemistry, pages 560 - 572..

MGH Chemistry, page 578.

Teacher’s Resource CM-ROM: BLM 14-2, “pH Calculation”, BLM 14-3, “Chapter 14 Test”.

Chemistry 11/12 Computerized Assessment Bank.