A TECHNOLOGY-ENHANCED INQUIRY-BASED CHEMISTRY CURRICULUM UNIT (ACIDS & BASES) DESIGNED TO INCREASE HIGH SCHOOL STUDENTS’ INTEREST IN STEM FIELDS AND STEM-RELATED CAREERS

By

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A project submitted to the Faculty of Education in conformity with the requirements for the degree of Master of Education

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Kingston, Ontario, Canada
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Abstract

Although a strong Science, Technology, Engineering, and Mathematics (STEM) education offers a pathway to a brighter future, opening up a wide range of interesting and exciting career opportunities, more than 50% of Canadian students do not complete the Grades 11 and 12 Mathematics and Science courses that allow them access to post-secondary STEM programs, apprenticeships, or entry-level employment positions (Amgen Canada Inc. & Let’s Talk Science, 2013). Therefore, it is vital to develop interest in STEM and enhance engagement in STEM areas at high school for students to build the strong foundation that is necessary to pursue advanced studies in STEM and participate in a future STEM-based workforce (Christensen, Knezek, & Tyler-Wood, 2014).

The purpose of this project was to develop a chemistry unit that demonstrates how content, pedagogy, and technology can be integrated to encourage study and careers in STEM. Using Ralph Tyler’s rationale (Tyler, 1949), backward design model (Wiggins & McTighe, 2011), constructivist views of teaching and learning (Kalpana, 2014), and the most advanced technological lab tools; the unit was developed to provide an implementable resource for teachers wanting to use inquiry-based activities in a high-tech environment. Ongoing formative assessment as students learn and for students to learn is emphasized throughout the unit using authentic lab activities that pique students’ interest in chemistry and support the development of a realistic vision of a STEM future that includes themselves.
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Introduction

Technologies are pervasive in almost every aspect of life with a growing demand to manufacture better and smarter products, improve health care, protect the environment, develop cleaner and more efficient domestic energy sources, and grow the economy. As scientific and technological innovations become more ubiquitous, there is a concomitant need for individuals with advanced knowledge in science, technology, engineering, and mathematics (STEM; Gordon, 2009). The growth of technologies has also been accompanied by an increased demand for STEM skills across sectors, including those traditionally considered “non-STEM” fields. As a result, learning STEM is important for the great majority of people because an increasing number of jobs entail the application of STEM skills including data analysis, problem solving, and the ability to apply and analyze evidence. Beyond the workplace, basic STEM literacy is required to make sound personal choices and informed decisions, for any and all of the myriad STEM-based choices we make each day, from health-care decisions to purchases at the grocery store (Bøe, Henriksen, Lyons, & Schreiner, 2011).

Rationale

Although a strong STEM education offers a pathway to a brighter future, opening up a wide range of interesting and exciting career opportunities, more than 50% of Canadian students do not complete the Grades 11 and 12 Mathematics and Science courses that allow them access to post-secondary STEM programs, apprenticeships, or entry-level employment positions (Amgen Canada Inc. & Let’s Talk Science, 2013). The majority of students who do not enroll in these courses began to lose interest in STEM during the high school years as a result of the perception that STEM subjects are boring, complicated, and/or difficult to learn (Drew, 2011). High school is a critical educational period for students. During these years, students develop
their own interests, recognize their academic strengths, and form their career beliefs (Christensen, Knezek, & Tyler-Wood, 2015). Therefore, it is vital to develop interest in STEM and enhance engagement in STEM areas during high school if students are to build the strong foundation that is necessary to pursue advanced studies in STEM and participate in a future STEM-based workforce (Christensen, Knezek, & Tyler-Wood, 2014). Internationally, efforts to increase high school students’ interest in STEM have been on the rise. Several programs have been launched to prepare more high school students for STEM subjects and inspire them to pursue STEM careers (Kier, Blanchard, Osborne, & Albert, 2014). Empirical studies of these programs show promise in improving students’ learning experiences, engagement, and attitudes toward STEM when inquiry instruction is implemented (Christensen et al., 2015; Furtak, Seidel, Iverson, & Briggs, 2012) and/or technology is integrated (Slykhuis & Krall, 2011; Xie & Reider, 2014). However, there are a few studies about STEM education that apply STEM curriculum and include STEM model classes or authentic STEM experiences (Christensen et al., 2015; Knezek, Christensen, Tyler-Wood, & Periaithiruvadi, 2013). More research is needed to investigate STEM experiences that pique students’ interest using authentic lab activities to support the development of a realistic vision of a STEM future that includes themselves.

**Purpose**

The purpose of this project was to develop a chemistry unit that demonstrates how content, pedagogy, and technology can be integrated to encourage study and careers in STEM. Using Ralph Tyler’s rationale (Tyler, 1949), the backward design model (Wiggins & McTighe, 2011), constructivist views of teaching and learning (Kalpana, 2014), and the most advanced technological lab tools (e.g., Vernier logger pro software and pH sensor); the unit was developed to provide an implementable resource for teachers wanting to use inquiry-based activities in a
high-tech environment. Ongoing formative assessment as students learn and for students to learn is emphasized throughout the unit using a suite of performance tasks and self-assessment tools.

**Approach to Learning Framework**

**Constructivist Theory**

This unit was developed based on learning that is derived from Constructivist Theory. The core concept of constructivism is that an individual learner actively constructs knowledge and meaning from his/her own experience through an adaptive learning process that integrates new knowledge into his/her existing cognitive structures (Cakir, 2008; Schunk, 1996).

Despite the “growth of constructivism as an epistemological commitment and instructional model that includes aspects of Piagetian, Ausubelian and Vygotskian learning theories; namely, the importance of ascertaining prior knowledge, or existing cognitive frameworks, as well as the use of dissonant events (relevant information) to drive conceptual change” (Cakir, 2008, p. 4), constructivism in learning “is not a unified perspective but rather is expressed in different forms” or models (Schunk, 1996, p. 209). One crucial difference among these forms is about the extent to which the model focuses on learners as independent individuals (psychological) in comparison to the social interactions between an individual and his social environment (social; Palincsar, 1998).

**Psychological Constructivism**

A psychological constructivist approach, influenced by Piaget’s work, focuses on the belief, knowledge, and inner psychology of individuals. These constructivists argue that individuals understand and interpret the new experience in a particular learning situation by fitting the new experiences or knowledge into pre-existing cognitive structures (schemes) in their minds. Piaget describes the process of incorporation of new information in relation to existing
schemes of information, concepts, or ideas as assimilation. Cognitive conflicts result when the new knowledge does not fit within the existing structure. To resolve these conflicts, the existing schemes modify in a process called “disequilibration” or “accommodation” allowing the integration of the new knowledge. A new balance or equilibrium is then restored within the cognitive system (Cakir, 2008; Kalpana, 2014).

**Social Constructivism**

Social constructivism, influenced by the views of Vygotsky, considers the social environment critical for learning. It assumes that “thinking is located in social and physical contexts not within individual’s mind” (Kalpana, 2014, p. 2). Using tools in these contexts such as cultural objects, language, and social institutions to socially interact and mentally internalize these interactions produces learning (Schunk, 1996). For example, by interacting with others during group discussion or peer collaboration, students share their views, learn from each other, and generate an understanding related to the concept studied (Kalpana, 2014).

Another exceptionally important assumption in Vygotsky’s (1978) constructivist theory is the zone of proximal development (ZPD), defined by his words as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p. 86). A cognitive change occurs in the ZPD as learners bring their own understandings to social interactions with teachers or more experienced people in the context. This conceptual change leads to learning new knowledge and constructing meanings when it is internalized in the learner (Schunk, 1996).
A Constructivist Science Classroom

The essence of constructivism is that knowledge is not transmitted among persons but rather is built up “either individually based on what student brings through prior experience or collaboratively by what participants contribute” (Kalpana, 2014, p. 2). Introducing a cognitive conflict disequilibrates the new knowledge which in turn produces conceptual change or learning; thus, to promote meaningful learning from a constructivist perspective, it is crucial to stimulate cognitive conflict by employing a student-centred environment that allows interaction of students’ beliefs with classroom instructional practices. In a constructivist science classroom, teachers do not stand in front of a group of students lecturing in a traditional way but rather they actively engage students in purposeful, hands-on activities that challenge students’ existing conceptions leading them to reconstruct their understanding and personal theories (Cakir, 2008).

Overview of Selected Literature

Inquiry-Based Science Learning

Scientific inquiry has been a standard in most policy reform documents during the last two decades (National Research Council, 1996). The National Science Education Standards define scientific inquiry as:

“Multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results” (National Research Council, 1996, p. 23).
More recently, the National Research Council (2005) has expanded their description of scientific inquiry activities to include laboratory experiences: “Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science” (p. 3).

Inquiry has been used in science education in a number of ways, ranging from the simple description of knowledge gain through applying the scientific method in well-designed activities to the complex instructional approach where teachers act only as facilitators and students actively guide their own learning process (Minner, Levy, & Century, 2010). Research has shown mounting evidence of the positive effects of integrating inquiry into science teaching and learning (Furtak et al., 2012; Minner et al., 2010). In their meta-analysis of inquiry-based science teaching, Furtak et al. (2012) compared and contrasted scientific inquiry in 37 studies published between 1996 and 2006 in terms of two dimensions: the cognitive dimension of inquiry and the guidance dimension of inquiry. The cognitive dimension consisted of four domains: conceptual structures and cognitive processes that were used during scientific reasoning; epistemic frameworks used when scientific knowledge was developed and evaluated; social interactions that shaped how knowledge was communicated, represented, argued, and debated; and procedural domain that described the methods of asking scientifically oriented questions, designing experiments, executing procedures, and analyzing data. The guidance dimension of inquiry identified the extent to which activities were guided by the teacher or student. The results of this meta-analysis indicated that engaging students in guided inquiry activities, specifically epistemic activities or the combination of procedural, epistemic, and social activities, has positive learning gains compared to traditional learning or unstructured student-led activities.
The implementation of inquiry-based science teaching programs is posited to help motivate and engage students in science learning (Minner et al., 2010), improve their academic readiness and achievement (Areepattamannil, 2012), increase their interest in STEM subjects and STEM careers (Christensen et al., 2015), and reduce their resistance behaviours toward science and technology (Sever & Guven, 2014).

Scientific investigations and hands-on activities play a distinctive role in inquiry-based science teaching and learning. During investigations and hands-on activities, students are required to use the scientific inquiry elements of questioning; stating a hypothesis; making a plan; conducting observations and experiments to generate artifacts; collecting information; drawing conclusions; and, communicating throughout the inquiry process (Wang, Zhang, Clarke, & Wang, 2014). The intended outcome of the scientific investigations and hands-on activities in this curriculum unit was that students develop a deeper understanding of scientific concepts, enhance their research and problem solving skills, develop positive attitudes toward science, and improve their academic achievement in science subjects (Areepattamannil, 2012; Wang et al., 2014).

**Technology-Enhanced Science Inquiry**

In their literature review of 143 articles on the use of educational technologies for teaching science between 2000 and 2010, Slykhuis and Krall (2011) systematically analyzed the different ways technology facilitated scientific inquiry in the examined studies: (a) collecting scientific information such as using Internet search programs, learning objects, and computers to find and/or review information; (b) collecting and analyzing data like using probeware and other software programs to collect and analyze data; (c) creating and using models of scientific phenomena including simulations, modeling, virtual reality, robotics, and virtual learning
environments; or (d) communicating such as using classroom response systems, blogging, and mediated chat. Slykhuis and Krall (2011) found that technology was recognized as an effective tool to promote and improve students’ scientific literacy and problem solving skills regardless of the way it was integrated.

The effectiveness of technology integration into science education in schools is recognized as a tool to promote and improve students’ scientific literacy and problem solving skills. The history of studies about the implementation of technology in science instruction shows an important trajectory of moving from lower-level concerns such as technical support toward the exploration of specific educational technology tools and pedagogical strategies that affect student learning, interest, and attitudes toward science (Slykhuis & Krall, 2011). For example, interacting with iPad applications (Boyce, Mishra, Halverson, & Thomas, 2014); using netbooks, web-based learning platform, and/or interactive online programs (Sun, Looi, & Xie, 2014; Zheng, Warschauer, Hwang, & Collins, 2014); performing experiments using probeware and computers (Zucker, Tinker, Staudt, Mansfield, & Metcalf, 2008); learning through educational video games (Anderson & Barnett, 2013); and creating robotic models (Cuperman & Verner, 2013) are purported to be forms of effective integration of technology in student-centred environments, where teachers act as facilitators in the learning process. Such effective interactions with technology in inquiry-based environments have been shown both to improve students’ academic achievement and increase their passion and enthusiasm for science (Swarat, Ortony, & Revelle, 2012).

More recently, scientists started to bring the cutting edge technological tools from research labs such as multi-agent computer simulations (Hmelo-Silver, Eberbach, & Jordan, 2014) and bifocal modeling (BM; Blikstein & Wilensky, 2007) and use them in schools to
Multi-agent computer simulations are systems built from thousands of very simple agents that behave according to simple rules. The overall patterns or behaviours at the macro level of these simulations are not directly actuated by any of the simple agents; but rather, arise as epiphenomenal to multiple local behaviours. Multi-agent simulations were successfully used to help students understand the concepts in their curricula; however, these simulations are ‘on-screen’ and are not connected to the investigations that students do in conventional school laboratories (Hmelo-Silver et al., 2014). In contrast, BM, which is a technological platform that enables students to connect computer models and sensors in real time, connects the virtual multi-agent simulation of a phenomenon or experiment to the physical world of that particular phenomenon or experiment (Blikstein & Wilensky, 2007). The basic idea of a BM platform is merging robotics/sensing and multi-agent computer simulations to provide the continuity between observation and theoretical model-building. It enables students to connect computer models and sensors in real time to validate, refine, and debug their computer models using real-world data. The process of BM consists of four major steps. First, using the NetLogo modeling-and-simulation environment, a computer algorithm of a particular scientific phenomenon is built. Second, a physical robotic model or an apparatus equipped with electronic sensors is constructed. Third, a special software component is developed to link the simulation and physical model in real time through a data logging board (the GoGo board). Finally, a computer interface is created to visualize the outcomes of virtual simulations and physical experiments side-by-side, compare results, and debug the simulation algorithm until it matches adequately the real world data and thus emulates the studied phenomenon (Blikstein, Fuhrmann, Greene, & Salehi, 2012; Blikstein & Wilensky, 2007). BM has been found to be engaging for students, providing effective learning experience and generating a deep engagement with the
phenomenon that has cognitive implications. It enables students to rapidly investigate their hypotheses, observe alternative outcomes, validate their own models and algorithms, and attend to phenomenal factors such as scale conversion, energy loss/friction, reversibility, time, synchronicity, and precision (Blikstein et al., 2012; Blikstein & Wilensky, 2007).

Despite the promising and positive research outcomes about integrating technology into science inquiry and the ways this integration can affect students’ interest and attitudes toward STEM, the majority of research focuses on the empirical examination of direct implementations of technology in science classrooms (Slykhuis & Krall, 2011). Supporting students’ inquiry through technology-enhanced instruction, however, requires specially-designed materials and specific resources that include model classes and authentic experiences (Christensen et al., 2015; Knezek et al., 2013). Further research is needed to investigate policies, procedures and models for teachers who want to plan and teach technology-enhanced, inquiry-based lessons that pique students’ interest in STEM using authentic lab activities. This project sought to address this gap, by preparing a research-based, inquiry focused, technology dependent chemistry curriculum unit about acids and bases. Using Ralph Tyler’s rationale (Tyler, 1949) and the backward design model (Wiggins & McTighe, 2011), the unit was developed to provide an implementation resource for teachers wanting to use inquiry-based activities in a high-tech environment. Technology integration in the unit was demonstrated in various ways including the use of online simulations and virtual experiments on acids and bases; using pH sensors and computer software for measuring, graphing, and analyzing the change in pH during an acid-base neutralization reaction; and applying BM to reconcile pH titration graphs of virtual simulations with pH titration graphs that are generated using pH sensors and real acid-base titration experiments.
Design and Methodology

Curriculum

Curriculum can be defined in many different ways. For the purpose of this project, I used the key term “curriculum” as a specific blueprint for achieving effective and engaging learning that is derived from desired goals. This curriculum is more than a list of topics or key facts and skills. It took content from local goals and external standards and shaped it into a plan that specifies the most appropriate experiences, activities, and assessments that might be used for achieving the desired goals (Egan, 2003). Having the desired learning goals as an end in mind, the unit described what the teachers need to do to achieve the results sought, what the learners should have achieved at the end of the unit, and what they need to do to achieve it (Wiggins & McTighe, 2011)

Understanding

I agree with Covey (1989) that:

“To begin with the end in mind means to start with a clear understanding of your destination. It means to know where you are going so that you better understand where you are now so that the steps you take are always in the right direction” (p. 98)

Therefore, I focused my design on students’ understanding not only around learning goals, but on engaging with “big ideas” that give meaning and connection to the discrete scientific facts and concepts. By understanding here I mean “being able to think, act flexibly, explain, justify, extrapolate, relate, and apply in ways that go beyond knowledge and routine skill” (Perkins, 1998, p.42). For students to gain the desired understating throughout the unit and become able to articulate and elaborate on the covered topics, I consolidated the unit with
technology-enhanced performance tasks and inquiry activities that go beyond the rote and the routine. I also provided a collection of suggestions about the ways in which teachers can find evidence of understanding in their students’ work for the purposes of assessment and evaluation. I did so by describing the ways collected evidence can determine the extent to which the desired results are on the way to being achieved (formative assessment) and to what extent they have been achieved at the end of the unit (summative assessment; Wiggins & McTighe, 2011).

**Assessment**

Rethinking assessment from the perspective of purpose and balance among the assessment purposes rather than method, shifts the emphasis to the intended end result (Earl & Katz, 2006). Consequently, I used authentic assessment for learning during the various activities throughout the unit to gauge the degree to which students know and how, when, and whether the students apply what they know. This family of assessments provides feedback to students to help them advance their learning. In addition to assessment for learning, I also included assessment tools for teachers to use as their students learn to help develop and support students’ metacognition by providing them with opportunities to critically analyze their own learning. For this purpose, I incorporated opportunities for students to reflect on their own learning and use teacher feedback from their reflections to make adjustments, adaptations, and even major changes to what they understand. At the end of the unit, I included summative assessment tools to measure what students have learned and to demonstrate whether they have achieved the desired goals and outcomes of the curriculum (Earl & Katz, 2006; Marsh & Willis, 2007).

**The Understanding by Design (UbD) Framework**

Using the UbD framework, I focused my planning process on the two key ideas of 1) teaching and assessing for understanding and learning transfer, and 2) designing the curriculum
unit “backward” from those end goals.

Backward design is “an approach to designing a curriculum or unit that begins with the end in mind and designs toward that end” (Wiggins & McTighe, 2011, p. 338). Designing backward means to think about the specific desired learning outcomes sought and the evidence of such learning before thinking about the instruction and learning activities. The idea of backward design is not new. For example, Polya (1945) discussed “thinking backward” more than 60 years ago as a strategy in problem solving that goes back to the Greeks:

“There is a certain psychological difficulty in turning around, in going away from the goal, in working backwards….yet, it does not take a genius to solve a concrete problem working backwards; anyone can do it with a little common sense. We concentrate on the desired end; we visualize the final position in which we would like to be. From what foregoing position could we get there?” (p. 230).

And, in his famous book, Basic Principles of Curriculum and Instruction, originally published in 1949, Ralph Tyler described the logic of backward design:

“Educational objectives become the criteria by which materials are selected, content is outlined, instructional procedures are developed, and tests and examinations are prepared…The purpose of a statement of objectives is to indicate the kinds of changes in the student to be brought about so that instructional activities can be planned and developed in a way likely to attain these objectives.” (p. 1, 45).

The backward design model is comprised of three stages. Stage 1 defines the worthy content, desired understanding, and curriculum expectations. It also structures the educational purposes; general learning outcomes; and essential overarching and topical questions that
encapsulate what students should know, understand, and be able to do in this unit. Stage 2
determines the effectiveness of learning through a collection of assessment evidence that is
needed to document and validate the degree to which the desired learning has been achieved.
Stage 3 plans and sequences learning experiences and instruction to support students’
understanding of facts, concepts, and principles and to equip them with the skills they need to
perform effectively and achieve the desired results (Wiggins & McTighe, 2011).

During the planning process of this unit, I used a set of UbD Standards corresponding to
each stage of backward design. These standards contributed to the curriculum design in three
ways: as criteria to use during development, for use in self-assessment and peer reviews of the
design, and for quality control and effectiveness of the completed unit. Wiggins & McTighe
(2011) summarize the UbD Design Standards in the four questions that follow.
1. To what extent does the design focus on the big ideas of targeted content?
2. To what extent do the assessments provide fair, valid, reliable, and sufficient measures of the
desired results?
3. To what extent is the learning plan effective and engaging?
4. To what extent is the entire unit coherent, with the elements of all three stages aligned?

**Technology Integration**

Technology is integrated in this chemistry unit in different ways ranging from using on-
line videos and virtual simulations that illustrate the theoretical concepts related to acids and
bases to using conductivity and pH sensors, computer software, and BM to connect virtual
simulations with real physical models in real time and reconcile any differences between them.

By using pH sensors and logger-pro software from Vernier (a company that pioneers
interfaces, data loggers, sensors, and graphing/analysis software), students are intended to
measure the change in pH during an acid-base neutralization experiment and sketch the pH graph for the titration process. Then, by using a virtual simulation of their experiment that is developed by a team of undergraduate students at the Faculty of Education in Queen’s University, students are intended to compare between the titration curve that is generated by using their physical system with a pH sensor and the titration curve that is generated by the computer virtual simulation in real time. Students are then expected to think of the factors that cause discrepancies between the virtual model and the real model, if any, and apply their understanding of these factors to make changes into the virtual model equations until the titration curve of the virtual simulation matches with the titration curve of the physical model (Blikstein et al., 2012; Blikstein & Wilensky, 2007).

**Unit Overview**

This Grade 10 unit comprises 15 lessons, some original and some adapted from Nelson. It enables students to develop an understanding of acid and base definitions in terms of hydrogen ion-transfer and extend their knowledge of chemical and physical properties of acids and bases. Students will investigate the differences between strong and weak acidic and alkaline solutions in relation to the degree of ionization or dissociation of the respective acidic/basic compounds and explore how pH and hydronium ion concentration values can be used efficiently to express the strengths of acids and bases. Students will examine acid-base neutralization reactions and represent these reactions by using overall, ionic, and net ionic equations. They will also investigate the process of acid-base titration and apply stoichiometric relationships to solve problems involved in buffering and antacid use. Students will further develop problem-solving and laboratory skills as they investigate the process of acid-base reaction, at the same time refine their ability to communicate scientific information.
This acid-base chemistry unit focuses on the important role chemistry plays in understanding the factors that affect human health and environment. It focuses on understanding the relationships among chemistry, technology, and mathematics; the way they affect our daily life; and on evaluating the impact of chemical technology on the environment. It is designed for Grade 10 and comes after the units of Chemical Reactions, Quantities in Chemical Reactions, and Solutions and Solubility that contain knowledge and skills necessary to form an understanding of Acid-Base behavior.
References


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A Technology-Enhanced Inquiry-Based Chemistry Curriculum Unit

Acids and Bases

A Unit for Grade 10
Written by: Sana’a Abu Eid
March 2016
### Unit Overview

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<th>Unit Title</th>
<th>Acids and Bases</th>
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<td>Subject Area</td>
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<td>Designed by</td>
<td>Sana’a Abu Eid</td>
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<tr>
<td>Time Frame</td>
<td>15 lessons (60 minutes each)</td>
<td>School District/ School</td>
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### Content Overview

This unit enables students to develop an understanding of acid and base definitions in terms of hydrogen ion-transfer and extend their knowledge of chemical and physical characteristic properties of acids and bases. Students will investigate the differences between strong and weak acidic and alkaline solutions in relation to the degree of ionization or dissociation of the respective acidic/basic compounds and explore how pH and hydronium ion concentration values can be used efficiently to express the strengths of acids and bases. Students will examine acid-base neutralization reactions and represent these reactions by using overall, ionic, and net ionic equations. They will also investigate the process of acid-base titration and apply stoichiometric relationships to solve problems involved in buffering and antacid use. Students will further develop problem-solving and laboratory skills as they investigate acid-base reaction process, at the same time refine their ability to communicate scientific information.

This acid-base chemistry unit focuses on the important role chemistry plays in understanding the factors that affect human health and environment. It focuses on understanding the relationships among chemistry, technology, and mathematics; the way they affect our daily life; and on evaluating the impact of chemical technology on the environment. It is designed for Grade 10 and comes after the units of Chemical Reactions, Quantities in Chemical Reactions, and Solutions and Solubility that contain knowledge and skills necessary to form an understanding of Acid-Base behavior.

### Keywords

Acid, hydronium ion, acidic hydrogen, ionization, base, hydroxide ion, dissociation, strong acid, strong base, weak acid, weak base, indicator, pH, buffer, neutralization, salt, ionic equation, net ionic equation, titration, standard solution.
Stage 1: Desired Goals

Curriculum Expectations: Established General Learning Outcomes

- Identify the factors that affect health, and explain the relationships among personal habits, lifestyle choices, and human health, both individual and social.
- Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.
- Recognize safety symbols and practices related to scientific and technological activities and to their daily lives, and apply this knowledge in appropriate situations.
- Demonstrate appropriate scientific inquiry skills when seeking answers to questions.
- Demonstrate curiosity, skepticism, creativity, open-mindedness, accuracy, precision, honesty, and persistence, and appreciate their importance as scientific and technological habits of mind.

What essential questions will be considered?

Overarching essential Questions:

- What role does knowing science play in building lifelong skills and habits that are essential for living in our modern world?
- How do chemists integrate scientific knowledge into daily life practices?

Topical essential questions:

- How is human activity affecting the balance of acids and bases in the environment?
- How does understanding acid-base chemistry improve people’s lives?

What understandings are desired? (2)

Students will understand that

- Physical and chemical properties of acids and bases are different and are related to their reactions in water.
- Acids and bases present in the soil of earth, the food we eat and the products we use (vinegar, antacid tablets, household cleaners, cosmetics, etc…). Amino acids make up the fabric of every organ in our bodies and are crucial to our existence.
- A major air pollution problem is acid rain, which is defined as precipitation with a pH of less than 5.0. Acid rain forms when sulfur dioxide and nitrogen oxides, released from industrial plants, combine with atmospheric moisture to create sulfuric acid and nitric acid.
- The properties of acids and bases and their reactions can be applied to solve environmental challenges associated with pollution (e.g., renewing the Great Lakes, neutralizing acid spills, scrubbing smokestack emissions). (2)

### What key knowledge and skills will students acquire as a result of this unit?

<table>
<thead>
<tr>
<th>Students will know:</th>
<th>Students will be able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key terms: Acid, hydronium ion, acidic hydrogen, ionization, base, hydroxide ion, dissociation, strong acid, strong base, weak acid, weak base, indicator, pH, buffer, neutralization, salt, ionic equation, net ionic equation, titration, standard solution.</td>
<td>Plan and conduct an inquiry to classify some common substances as acidic, basic, or neutral based on their physical and chemical properties (i.e. reaction with a metal, reaction with a carbonate, using acid-base indicator or pH test strips, electrical conductivity,) [C, IP, PR, AI]. (2)</td>
</tr>
<tr>
<td>Definition of an acid and a base in term of hydrogen transfer.</td>
<td>Plan and perform an experiment to investigate the role buffers play in controlling acidity (e.g., compare between buffered aspirin and aspirin, using quantitative analysis) [IP, PR, AI, C]. (2)</td>
</tr>
<tr>
<td>The physical and chemical properties of acids and bases and the central role of water in the chemistry of acids and bases.</td>
<td>Plan and perform an experiment to investigate applications of acid–base reactions in common products and processes (e.g., compare the effectiveness of different products of antacid, using quantitative analysis) [IP, PR, AI, C]. (2)</td>
</tr>
</tbody>
</table>
| The relationship between the strength of acids and bases, their degree of dissociation or ionization and the electrical conductivities of their solutions. | IP: Initiating and planning  
C: Communicating  
AI: Analyzing and interpreting  
PR: Performing and recording |
| pH scale as a tool to classify solutions into acidic, basic and neutral.            |                                                                             |
| The importance of a buffer in controlling pH (i.e., blood, buffered aspirin).     |                                                                             |
| The process of acid-base neutralization (i.e., an acid reacts with a base to form a salt and often water). |                                                                             |
| Applications of acid-base reaction such as using antacid tablets to neutralize excess acid in stomach. |                                                                             |
| The difference between overall, ionic and net ionic equations for an acid-base reaction. |                                                                             |
| Strategies for doing acid-base titrations, and simple calculations of results from titration data. |                                                                             |
| Drawing and interpreting titration curves.                                         |                                                                             |

(2) The Ontario Curriculum Grade 10 Science, 2008. Retrieved from:  
Stage 2 - Assessment Evidence

Performance Tasks

1. **Properties of Acids and Bases:** Student plan and conduct an inquiry to classify some common substances as acidic, basic, or neutral based on their physical and chemical properties (i.e. using acid-base indicator, pH test strips, pH meter, reaction with a metal, reaction with a carbonate, electrical conductivity). Students summarize their results in a power point presentation and present it in class.

2. **Testing Aspirin:** Students will plan and perform a titration experiment, using titration tool-kit from Vernier, to investigate the difference between Aspirin and buffered Aspirin. Students submit their findings in a lab report format.

3. **Which Antacid is more Effective?** Using the titration tool-kit from Vernier, students will design and perform an acid-base neutralization experiment to compare the effectiveness of different products of antacid tablet (x and y). Students will write a report explaining the product they think is more effective and the rationale behind their selection (assessment task A).

4. **Construction of a Titration Curve:** Students will compare a titration graph that is generated from a virtual titration simulation to a titration graph that is generated by using the physical experiment of titration. Then, they will investigate the factors that affect the graph and change the code equations of the virtual simulation to reconcile with the real physical data (assessment task B).

Other Evidence

- Quiz and Unit Test.
- Topic Review Question sets: students demonstrate their understanding to every topic taught by answering a set of questions related to that topic.
- Prompt: How does understanding acid-base chemistry improve people’s lives?
- Chemistry Journal:
  - Students check labels of different products and food items and list acids and bases that present in them
  - Students summarize three applications of acid-base reactions (e.g.: antacids, buffers, acidic soil treatment)

Student Self-Assessment and Reflection

Self-assess lab activity 1: (Properties of Acids and Bases) using perform an activity checklist. (3)

Self-assess lab activity 2: (Testing Aspirin) using Perform An Activity Checklist. (3)

Self-assess lab activity 3: (Which Antacid is more Effective?) using design your own investigation checklist. (3)

Self-assess lab activity 4: (Construction of a Titration Curve) using design your own investigation checklist. (3)

Reflect on the impact of knowledge: students discuss the ways knowledge of acids and bases affected their daily lives.

## Stage 2: Assessment Task A Blueprint

### What understandings or goals will be assessed through this task?

Students will plan and perform an acid-base reaction experiment to compare the effectiveness of different brands of antacid tablets (x and y).

### Task Overview

A pharmaceutical industries company is working on developing two new products of antacid tablets (x and y). The company has sent samples of the two new products to a research analytical laboratory where you are working as a chemist. Your lab manager asked you to test the two samples for effectiveness as antacid products.

Task: Using the chemicals of 0.2 M HCl, 0.2 M NaOH and phenolphthalein only, in addition to any glassware you need, plan and perform an acid-base experiment to compare the effectiveness of the two different products of antacid (samples x and y). Write a report to your lab manager explaining your findings.

### What student products and performances will provide evidence of desired understandings?

Findings
Lab report

### By what criteria will student products and performances be evaluated?

- Strategic plan followed during lab work
- Results obtained
- Effective data analysis and interpretation
- Proper lab report form
### Stage 2: Assessment Task B Blueprint

<table>
<thead>
<tr>
<th><strong>What understandings or goals will be assessed through this task?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will plan and perform an investigation to compare between a titration graph that is generated through a virtual simulation and a titration graph that is generated by using a physical titration experiment.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Task Overview</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Which titration curve is correct?</td>
</tr>
</tbody>
</table>

Task: Use the pH sensor and logger-pro software from Veriner to measure the change in pH during an acid-base titration experiment and sketch the pH titration graph. Then, use the provided virtual simulation to generate a pH titration curve of the same experiment. Compare between the curve that is generated by using the physical system with pH sensor and the curve in the computer virtual model. Which curve is the accurate one? Explain your answer. Predict the factors that cause discrepancies between the virtual model and the real model, if any, and use these factors to make changes into the virtual model equations until the titration curve of the virtual simulation reconciles with the curve of the physical model.

<table>
<thead>
<tr>
<th><strong>What student products and performances will provide evidence of desired understandings?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Findings</td>
</tr>
<tr>
<td>Lab report that explains findings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>By what criteria will student products and performances be evaluated?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic plan followed during lab work</td>
</tr>
<tr>
<td>Results obtained</td>
</tr>
<tr>
<td>Effective data analysis and interpretation</td>
</tr>
<tr>
<td>Proper lab report form</td>
</tr>
</tbody>
</table>
## Stage 3: Learning Plan

<table>
<thead>
<tr>
<th>Class 1: Introduction to acids and bases (60 min)</th>
<th>Instructional Strategies</th>
<th>Assessment</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you familiar with the term acid? Base?</td>
<td>Presentation of essential questions</td>
<td>Exit Question: Why do you think we should study acids and bases?</td>
<td>Occurrence of acids, application of calcium hydroxide, Textbook</td>
</tr>
<tr>
<td>Have you ever used something that contained an acid or a base?</td>
<td>Discussion of guiding questions</td>
<td>Chemistry Journal: Check labels of different products and food items for acids and bases. Write a list of acids and bases that present in each item.</td>
<td></td>
</tr>
<tr>
<td>Do acids and bases exist naturally in the environment or are they man made?</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classes 2-4: Properties of acids and bases (3 periods, each 60 min)</th>
<th>Instructional Strategies</th>
<th>Assessment</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>What properties do you think acids and bases have?</td>
<td>Lab activity 1: Properties of acids and bases</td>
<td>Results of lab activity 1</td>
<td>Presentation assessment Rubrics, Lab activity 1: Self assessment checklist, Quiz 1: Properties of Acids and Bases, Textbook</td>
</tr>
<tr>
<td>How are acids and bases alike? How are they different?</td>
<td>Students’ presentations of their results</td>
<td>Students’ presentations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Properties of acids and bases summary: Venn Diagram</td>
<td>Exit Question: what is an acid? What is a base?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Review Question set 1: Properties of acids and bases</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Quiz on properties of acids and bases</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class 5: Defining Acids and Bases- A Submicroscopic Look (60 min)</th>
<th>Instructional Strategies</th>
<th>Assessment</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do you think acids and bases have different properties?</td>
<td>Concept development</td>
<td>Review questions set 2</td>
<td>Acid ionization, Base dissociation, Textbook</td>
</tr>
<tr>
<td></td>
<td>Discussion:</td>
<td>Practice writing ionization/dissociation equations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Definition of an acid and acid ionization in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Definition of a base and base dissociation in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Writing chemical equations for acid ionization and base dissociation in water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Class 6: Strengths of acids and bases - pH scale (60 min)

<table>
<thead>
<tr>
<th>What does the term pH on a water bottle or cosmetic product mean?</th>
<th>Demonstration: who has just the right voice?</th>
<th>Summary of findings from animations</th>
<th>Acid-base solutions</th>
<th>pH Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is pH scale?</td>
<td>PhET animations: Investigation of the relationship between: - strength of an acid or a base, - degree of ionization of an acid or a base, - electrical conductivities, - and pH</td>
<td>Review Questions set 3</td>
<td>Textbook</td>
<td></td>
</tr>
<tr>
<td>How do we use pH scale to classify solutions into acidic, basic and neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Class 7-10: Acid-Base Reaction (4 periods, each 60 min)

<table>
<thead>
<tr>
<th>What happens when an acid reacts with a base?</th>
<th>Discussion: Neutralization reactions</th>
<th>Chemistry Journal: summarize differences between buffered aspirin and regular aspirin</th>
<th>Buffers</th>
<th>Textbook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice</td>
<td>Writing reaction equations</td>
<td>Lab report for activity 2</td>
<td>Self assessment checklist: Design your own investigation</td>
<td>Task assessment: Comparing antacids</td>
</tr>
<tr>
<td>Lab activity 2</td>
<td>Lab report for activity 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion: Acid-base reaction applications: buffers, antacids, acid rain, acidic soil treatment</td>
<td>Lab activity 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Class 11-14: Construct Titration Curve (4 periods, each 60 min)

<table>
<thead>
<tr>
<th>What are the factors that affect the shape of pH titration curve?</th>
<th>Discussion: the change in pH during neutralization reactions</th>
<th>Product: a virtual simulation of titration that generates a titration curve similar to the titration curve produced by physical titration experiment</th>
<th>Self assessment checklist: Design your own investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab activity 4</td>
<td>Lab report for activity 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Class 15: Essential Questions (60 min)

- What role does knowing science play in building lifelong skills and habits that are essential for living in our modern world?
- How do chemists integrate scientific knowledge into daily life practices?
- How is human activity affecting the balance of acids and bases in the environment?
- How does understanding acid-base chemistry improve people’s lives?

<table>
<thead>
<tr>
<th>Discussion of essential questions</th>
<th>Prompt: answer the essential question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How does understanding acid-base chemistry improve people’s lives?</td>
</tr>
<tr>
<td></td>
<td>Students reflect the ways knowledge of acids and bases affected their daily lives.</td>
</tr>
</tbody>
</table>

|  |
| --- | --- |
|  | Textbook |

### Unit Test
### Stage 3: Class Organizing Chart

<table>
<thead>
<tr>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
</table>
| - Hook students with a discussion about acids in food.  
- Introduce the essential questions.  
- Have students share their prior knowledge of acids and bases.  
- Show Occurrence of acids video clip.  
- Discuss with students whether they think acids and bases naturally exist in the environment or they are man-made.  
- Show application of calcium hydroxide animation.  
- Exit Question Card: Why do you think we should study acids and bases?  
- H.W.: Check labels of different products and food items for acids and bases. Write a list of acids and bases that present in each item in your Chemistry Journal.  | - Lab activity 1: Properties of acids and bases.  
- Remind students by safety Rules.  
- Observe and guide students during their lab work.  | - Assess and give feedback on students’ presentations.  
- Ask students to define acids and bases in term of their properties.  

<table>
<thead>
<tr>
<th>Class 4</th>
<th>Class 5</th>
<th>Class 6</th>
</tr>
</thead>
</table>
| - Summarize properties of acids and bases using Venn diagram.  
- Give quiz to assess students understanding.  | - Show acid ionization animation.  
- Discuss with students the definition of acid in term of producing hydronium ions.  
- Show base ionization animation.  
- Discuss the definition of base in term of producing hydroxide ions in water.  
- Emphasize on the role water plays in the chemistry of acids and bases.  
- HW: Review questions set 2: Practice writing ionization equations.  | - Ask students to read the pH value on a water bottle. Ask them: what does that value mean?  
- Demonstrate how an indicator solution changes color when pH of the solution changes.  
- Show PhET animation on strength of acids and bases.  
- Have students write a sentence that summarizes the relationship between strengths of acids and bases, degree of their ionization, electrical conductivities of their solutions and pH of their solutions.  
- Show PhET animation on pH scale.  
- Have students draw and label a pH scale.  
<table>
<thead>
<tr>
<th>Class 7</th>
<th>Class 8</th>
<th>Class 9</th>
</tr>
</thead>
</table>
| • Discuss neutralization reactions.  
• Practice writing neutralization equations. | • Lab activity 2  
• Remind students by safety rules.  
• Observe and guide students during their lab work.  
• HW: Lab report. | • Show buffer animation and discuss buffers.  
• Have students search and discuss for the difference between buffered aspirin and regular aspirin.  
• Discuss acid-base reaction applications such as antacids, building damage by acid rain and acidic soil treatment.  
• Ask students to write their summaries in the chemistry journal. |

<table>
<thead>
<tr>
<th>Class 10</th>
<th>Class 11</th>
<th>Class 15</th>
</tr>
</thead>
</table>
| Lab activity 3  
• Remind students by safety rules.  
• Observe and guide students during their lab work.  
• HW: Lab report. | • Lab activity 4  
• Remind students by safety rules.  
• Observe and guide students during their lab work. | • Display and discuss unit essential questions  
• Prompt:  
Ask students how they think understanding acid-base chemistry improve people’s lives.  
• Have students discuss the ways knowledge of acids and bases affected their daily lives. |

<table>
<thead>
<tr>
<th>Class 12-14</th>
<th></th>
</tr>
</thead>
</table>
| • Predict the factors that cause discrepancies between the titration curve generated by the virtual simulation and the titration curve generated by using the physical model, if any.  
• Use these factors to make changes into the virtual model equations until the titration curve of the virtual simulation reconciles with the curve of the physical model. |
### Stage 3: WHERE TO

1. Begin with an entry question (does a human body contain an acid?) to hook students into considering the crucial role acids play in their lives. **H**
2. Introduce the Essential Questions and discuss the culminating unit performance tasks. **W**
3. Note: key vocabulary terms are introduced as needed by the various learning activities and performance tasks. Students read and discuss relevant selections from the science textbook to support the learning activities and tasks. **E**
4. Have students share their prior knowledge of acids and bases. **H**
5. Show Occurrence of acids video clip. **E**
6. Discuss with students whether they think acids and bases naturally exist in the environment or they are man-made. **E**
7. Show application of calcium hydroxide animation to emphasize on the uses and applications of acids and bases. **E**
8. Have students work in pairs on Lab activity 1: Properties of acids and bases. **E-2**
9. Have students present their results. This presentation will be peer-& teacher-assessed. **E-2, T**
10. Working in cooperative groups, students analyze their lab results, summarize properties of acids and bases using Venn diagram to come up with a definition for an acid and a base in term of their properties. **E, E-2, R**
11. Give quiz on acids and bases properties. **E**
12. Show acid ionization animation. **E**
13. Discuss with students the definition of acid as a substance that produces hydronium ions when dissolved in water. **E**
14. Working in cooperative groups, students practice writing ionization equations for some common acids. **E, E-2**
15. Show base ionization animation. **E**
16. Have students conclude the species produced when bases dissolve in water, OH-. **E**
17. Working in cooperative groups, students practice writing ionization equations for some common bases. **E, E-2**
18. Emphasize on the role water plays in the chemistry of acids and bases. **E**
19. Have students read the pH value on a water bottle, cosmetic product. Ask them what they think that value means. **E**
20. Demonstrate how the color an indicator solution changes with pH though “Who has just the right voice?” activity. **E**
21. Have students work on PhET animations on strength of acids and bases and pH scale. **E, E-2**
22. Have students summarize, in one sentence, their understanding of relationship between strengths of acids and bases, degree of their ionization, electrical conductivities of their solutions and pH of their solutions. **E-2, R**
23. Have students draw and label a pH scale. **R**
24. Working in cooperative groups, have students discuss and practice writing neutralization equations in term of hydrogen transfer. **E, E-2**
25. Have students work in pairs on lab activity 2: Testing Aspirin. **E-2, T**
26. Show and discuss buffer animation. **E**
27. Have students search and discuss for the difference between buffered aspirin and regular aspirin. **E**
28. Have students discuss other applications of acid-base reactions such as antacids, building damage by acid rain and acidic soil treatment. **E**
29. Have students work in pairs on lab activity 3: Which Antacid is more effective? **E-2, T**
30. Display and discuss unit essential questions. **W**
31. Students respond to written prompt: How do acids and bases influence peoples’ lives? (These are collected and graded by teacher). **E-2**
32. Students do the Unit test. **E**

**W:** Ensure that students understand **WHERE** the unit is headed, and **WHY.** **H:** **Hook** the students in the beginning and **HOLD** their attention throughout. **E 1:** **EQUIP** students with necessary experiences, tools, and knowledge. **R:** Provide students with numerous opportunities to **RETHINK** big ideas. **E 2:** Build in opportunities for students to **EVALUATE** progress and self-assess. **T:** Be **TAILORED** to reflect individual talents, interests, styles, and needs. **O:** Be **ORGANIZED** to optimize deep understanding as opposed to superficial coverage.
Appendix A: Question Bank

1) Multiple Choice

1. One physical property of acids is a _____.
   a. slippery feel  c. sour taste
   b. pink color     d. presence of hydrogen

2. An unknown substance dissolves easily in water, and turns litmus paper red. The substance is most likely a (n)?
   a. base                  c. salt
   b. electrolyte            d. acid

3. For which compound is the formula correct?

<table>
<thead>
<tr>
<th>compound</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Ammonia</td>
<td>NH₄</td>
</tr>
<tr>
<td>b Sulphuric acid</td>
<td>H₂SO₃</td>
</tr>
<tr>
<td>c Sodium hydroxide</td>
<td>NaOH</td>
</tr>
<tr>
<td>d Nitric acid</td>
<td>HNO₂</td>
</tr>
</tbody>
</table>

4. Acids react with carbonates to produce _____.
   a. hydrogen     c. a hydronium ion
   b. a base       d. carbon dioxide

5. An example of a polyprotic acid is _____.
   a. HCl            c. H₂SO₄
   b. HC₂H₃O₂         d. HCN

6. Acids react with bases, carbonates and metals. Which of these reactions produce a gas?

<table>
<thead>
<tr>
<th>Reaction of acid with a</th>
</tr>
</thead>
<tbody>
<tr>
<td>base</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>c</td>
</tr>
<tr>
<td>d</td>
</tr>
</tbody>
</table>
7. Ammonia is considered to be a base because it _____.
   a. loses hydroxide ions in water  c. contains hydrogen
   b. contains the hydroxide ion      d. accepts hydrogen ions

8. The weak acid in the following list is _____.
   a. hydrochloric acid               c. nitric acid
   b. sulfuric acid                  d. acetic acid

9. Acids produce _____ in water.
   a. OH\(^+\)                        c. H\(_3\)O\(^+\)
   b. H\(_2\)O                         d. OH\(^-\)

10. In an acid, a (n) _____ can be transferred to water.
    a. H\(^+\)                           c. H\(_3\)O\(^+\)
    b. H\(_2\)O                           d. OH\(^-\)

11. The reaction between an acid and a base is a (n) _____.
    a. synthesis reaction              c. double displacement reaction
    b. neutralization reaction         d. both b and c

12. Which of the following is the best indicator of the number of hydronium ions in a solution?
    a. The pH of the solution              c. The colour of the solution in the presence of an indicator
    b. The mass of the solution              d. The amount of water in the solution

13. The weak base in the following list is _____.
    a. Sodium hydroxide                   c. ammonia
    b. Vinegar                              d. Potassium hydroxide

14. An acidic solution would have a pH of _____.
    a. less than 7                         c. 7 or above
    b. more than 7                        d. 7 or below

15. In a titration, the _____ is the solution for which the concentration is known.
    a. indicator                           c. normal solution
    b. hydrate                             d. standard solution
16. H₃O⁺ units are also known as ____.
   a. hydrogen ions  
   b. hydronium ions
   c. hydroxide ions  
   d. hydroxyl groups

17. A process that uses a solution of known concentration to find the concentration of another solution is called ____.
   a. hydration  
   b. neutralization
   c. ionization
   d. titration

18. A(n) ____ is a substance that produces H⁺ ions in a water solution.
   a. acid  
   b. base
   c. salt
   d. alcohol

19. A(n) ____ is a substance that produces OH⁻ ions in a solution.
   a. acid  
   b. base
   c. salt
   d. alcohol

20. ____ measures how acidic or basic a substance is.
   a. An ester  
   b. A base
   c. pH
   d. The hydronium ion

21. ____ change color in the presence of an acid or a base.
   a. Acids  
   b. Glycerins
   c. Buffers
   d. Indicators

22. A ____ is a compound formed in solution from the negative ion of an acid and the positive ion of a base.
   a. detergent  
   b. glycerin
   c. salt
   d. soap

23. A(n) ____ comes from an alcohol that is not a base but has a hydroxyl group.
   a. ester  
   b. glycerin
   c. salt
   d. soap

24. A bitter taste and a slippery feel are clues that a solution is probably a(n) ____.
   a. acid  
   b. base
   c. hydrate
   d. salt
25. The formula HCl stands for ____.
   a. the hydronium ion       c. hydrogen peroxide
   b. hydrochloric acid       d. sodium hydroxide

26. Ammonia is a weak base because it produces ____ ions in solution.
   a. strong                  c. only a few
   b. weak                   d. many

27. ____ of a solution refers to the ease with which an acid or base forms ions in solution.
   a. Acidity                c. pH
   b. Concentration          d. Strength

28. A base that only partly ionizes in a solution is a ____ base.
   a. concentrated           c. strong
   b. dilute                d. weak

29. In a chemical equation, a single arrow that points at the ions that are formed indicates a ____ acid or base.
   a. strong                 c. neutral
   b. weak                   d. concentrated

30. In a ____ reaction, an acid and a base produce a salt and water.
   a. decomposition          c. dilute
   b. neutralization         d. concentrated

31. Figure -1 above shows ____.
   a. neutralization of an acid          c. ionization of an acid
   b. neutralization of a base           d. ionization of a base

\[ \text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- \]

*Figure 1*
32. Coffee has a pH of about 5. Coffee is ____.
   a. extremely acidic
   b. extremely basic
   c. somewhat acidic
   d. somewhat basic

33. Blood contains compounds called ____ that allow small amounts of acids or bases to be absorbed without harmful effects.
   a. esters
   b. buffers
   c. enzymes
   d. precipitates

34. Metal ions in water can react with soap to form ____.
   a. acid-base indicators
   b. detergents
   c. salts
   d. soap scum

35. To neutralize gastric juices in your stomach, antacids contain ____.
   a. bases
   b. H\(^+\) ions
   c. hydronium ions
   d. Phenolphthalein

36. A substance that does NOT conduct an electric current when it forms a solution is a(n) ____.
   a. electrolyte
   b. nonelectrolyte
   c. liquid
   d. solid

37. Which of these acids could be hydrochloric acid?

   a. X Or Z
   b. X Only
   c. Y Only
   d. X,Y or Z
38. The pH values of four solutions are shown.

<p>| | | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>P</td>
<td></td>
<td>Q</td>
<td></td>
<td>R</td>
<td></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mixing combinations of these solutions can give a solution of pH 6.
Which combination of solutions could **not** do this?
- a. P and R
- b. P and S
- c. Q and R
- d. R and S

39. Gas X is passed into water as shown.

The pH of the water changes from 7 to 10.
What is gas X?
- a. ammonia
- b. carbon dioxide
- c. nitrogen
- d. sulphur dioxide

II) **The following table summarizes some properties of four compounds. Complete the table by supplying the correct information in the spaces provided.**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Acid or base</th>
<th>Ionization equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC₂O₃O₂</td>
<td>acid</td>
<td>HC₂H₃O₂ + H₂O ↔ H₃O⁺ + C₂H₃O₂⁻</td>
</tr>
<tr>
<td>RbOH</td>
<td>a.</td>
<td>b.</td>
</tr>
<tr>
<td>HCN</td>
<td>acid</td>
<td>c.</td>
</tr>
<tr>
<td>H₃PO₄</td>
<td>d.</td>
<td>e.</td>
</tr>
</tbody>
</table>
III) **Use the information listed below to categorize each compound as definitely an acid, definitely a base, or possibly an acid or a base.**

Compound A is highly corrosive.
Compound B will be red when universal indicator is added.
Compound C in solution feels slippery.
Compound D reacts with an indicator to produce a change in its color.
Compound E has a bitter taste.
Compound G has the chemical formula H2SO4.
Compound H has the chemical formula NaOH.

Classify the correct compound in the correct column below:

<table>
<thead>
<tr>
<th>Definitely an acid</th>
<th>Definitely a base</th>
<th>Possibly an acid or a base</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IV) **Complete the Following Equations**

1. H₂SO₄ + Zn →

2. HCl + CaCO₃ →

3. HCl + NaOH →
V) **Fill in the following Table**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Color in acid</th>
<th>Color in base</th>
</tr>
</thead>
<tbody>
<tr>
<td>litmus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>phenolphthalein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl orange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VI) **Answer the following Questions**

1. Ammonia is a base.
   
   A. Name a particle that an ammonia molecule can form in an aqueous solution.
   
   B. Write an equation for ammonia acting as a base.
   
   C. Given aqueous solutions, 0.1 M of sodium hydroxide and ammonia, describe how you could show that ammonia is the weaker base.
   
   D. State one use for ammonia.

2. Give the formula for sodium hydroxide, and identify it as a strong base or a weak base.

3. Write the balanced equation for the reaction when hydrochloric acid reacts with magnesium.
4. Write the balanced equation for the reaction of sulfuric acid with potassium carbonate.

5. After using soap to wash dishes by hand, it is sometimes difficult to keep your hands from remaining slick. Explain why rinsing your hands in lemon juice would make them less slick.

6. Calcium carbonate is the major component of limestone and marble. Sulfuric acid is one of the major components of acid rain. Write a balanced chemical reaction that shows how sulfuric acid reacts with calcium carbonate.

7. Hard water deposits around sinks may be composed of calcium carbonate. You can buy commercial cleaners to remove these insoluble compounds, or you could use something from the kitchen. What might you try?
Appendix B: Performance Tasks Procedures
Properties of Acids and Bases (Adapted from Nelson Science Connections 10, Teacher’s Resources, 2011)

Properties of Acids and Bases

**OVERALL EXPECTATIONS:** A1, C1, C2, C3

**SPECIFIC EXPECTATIONS**
- Developing Skills of Investigation and Communication: C2.1, C2.6
- Understanding Basic Concepts: C3.1, C3.2

The full Overall and Specific Expectations are listed on pages 183–185.

**KEY CONCEPTS**
- Acids and bases have special chemical properties.

**EVIDENCE OF LEARNING**
Look for evidence that students can
- recognize typical properties of acids and bases
- safely perform laboratory activities using acids and bases
- use the properties of acids and bases to classify an unknown compound as an acid or a base

**SCIENCE BACKGROUND**

- **Electrical Conductivity of Acids**
  - The electrical conductivity of a solution depends on the number of ions present. A greater number of ions results in a greater electrical conductivity. Conversely, a small number of ions results in low conductivity. Even though acids are molecular compounds, they form hydrogen ions (H⁺) and negative polyatomic or monatomic ions in solution. The process by which a molecular compound forms ions in solution is called ionization.
  - The number of ions that an acid forms in solution depends on how strong the acid is. A strong acid completely—or almost completely—ionizes in solution. For example, when hydrochloric acid (HCl), which is a strong acid, is placed in water, all the HCl molecules present ionize into H⁺ and Cl⁻ ions. A weak acid ionizes little in solution. Because of the varying degree of ionization, strong acids conduct electricity well, while weak acids do not.

- **Electrical Conductivity of Bases**
  - Most bases are ionic compounds, so one might expect bases to form ions in solution. The process by which an ionic compound breaks apart to form ions in solution is called dissociation. Bases dissociate to form metal ions and hydroxide (OH⁻) ions. The degree of dissociation that occurs depends on the solubility of the base. Thus, bases that do not dissolve in water are weak conductors.
TEACHING NOTES

Student Safety

Review the following safety rules with students:
- Wear eye protection and a lab apron to protect against possible splashes. Although the acids and bases used in this activity are dilute, contact with the solutions can damage human tissue and clothing.
- If a spill does occur, inform your teacher immediately and be sure that spills are thoroughly cleaned up.
- Do not taste any laboratory materials or substances. Do not touch your mouth or nose after handling any of the materials unless you thoroughly wash your hands first.
- Thoroughly wash your hands at the end of the activity.

- Have students work in small groups for this activity.
- Any impurities on the equipment can affect the results of the activity. Rinse all glassware and the electrodes on the conductivity tester with distilled water before beginning the activity.
- Emphasize that this activity is qualitative, not quantitative. For example, the reaction of magnesium with acid will occur more quickly with a strong acid. However, bases do not react with metals at all. If the unknown solution shows any reaction at all with magnesium, the solution is an acid, even if the reaction is much less than it was with hydrochloric acid.
- Instruct students to dispose of all solutions in a container provided for that purpose. Check the pH of this solution. Neutralize it, if necessary, and then dispose of it down the drain with plenty of water.
- You may choose to distribute BLM 5.9-1 Perform an Activity: Properties of Acids and Bases for students to use as they complete the activity.

Purpose

- Students observe various properties of acids and bases such as conductivity, reaction to magnesium or carbonate, and reactions to indicators. Students will then apply these tests to identify unknown substances as acids or bases.

Equipment and Materials

- The conductivity tester can be purchased, or it can be made from wires, a battery, a small bulb, and alligator clips.
- Magnesium reacts well with acids, but other metals can be used instead of magnesium. Aluminum, zinc, iron, or another active metal can be used.
- Toothpicks are used to add solids to the wells. Flat toothpicks are easier to use than round ones.
- Students can use powdered chalk, which is calcium carbonate (CaCO₃), instead of baking soda.
- Prepare 0.1M solutions of hydrochloric acid and sodium hydroxide. Because the solution process for sodium hydroxide is exothermic, prepare this solution in time for it to cool to room temperature before use. To prepare 0.1M hydrochloric acid, add 4.2 mL of 12M hydrochloric acid to distilled water to make 500 mL of solution. To prepare 0.1M NaOH solution, dissolve 2.0 g of solid NaOH in distilled water to make 500 mL of solution.
- For Part B, prepare solutions of various acids and bases as the unknown solutions. The HCl and NaOH solutions used in Part A can be used. White

Related Resources

Gizmos: pH Analysis, pH Quad Colour Indicator
Abelow, Benjamin. Understanding Acid-Base. Lippincott Williams & Wilkins, 1998.
Science Connections 10 ExamView® Test Bank
Science Connections 10 Teacher eSource SUITE Upgrade
Science Connections 10 website www.nelson.com/scienceconnections/10
vinegar can also be used as an acid. Dissolve 3.7 g of Ca(OH)$_2$ in water to make 500 mL of a 0.1M Ca(OH)$_2$ solution.

- If appropriate for the individual class, students could be invited to bring in household products to test. Products must be transported sealed in their original containers.

**Procedure**

- Advise students that their procedures must contain appropriate safety cautions, and must be approved before they conduct the activity.
- Caution students not to let the electrodes of the conductivity tester touch each other while checking for electrical conductivity. Have them wash the electrodes with distilled water in between testing different solutions.
- Have students place the well plate on a piece of white paper so colours can more easily be seen.
- Review students’ procedures for each test, and if necessary assist students in revising their procedures, before giving your approval for them to continue.

**Analyze and Evaluate**

(a) Based on the results of the activity, acids conduct electricity, turn bromothymol blue yellow, turn blue litmus red, and react with magnesium and sodium hydrogen carbonate. Bases conduct electricity, turn bromothymol blue, turn red litmus blue, and do not react with magnesium and sodium hydrogen carbonate.

(b) Sample answer: We choose to use red and blue litmus paper because they were the quickest and easiest tests.

(c) Answers will vary. Check that students’ classifications are correct and that they have justified their classifications based on the properties of the unknown solutions.

**Apply and Extend**

(d) The formulas for acids often begin with at least one hydrogen. The formulas for bases contain OH.

**DIFFERENTIATED INSTRUCTION**

- To help develop students’ skills outside of their strengths it helps to group students with different intelligences during lab activities. For example, a logical/mathematical learner can help a musical/rhythmic learner, or a visual/spatial learner develop and record a procedure to test for the properties of acids and bases in this activity.
- Using a choice board, have students choose the format they wish to use to communicate their learning. For example, a visual/spatial student may wish to create a montage of the lab using a digital camera and multimedia software.

**LITERACY TIPS AND ENGLISH LANGUAGE LEARNERS**

- Many words have more than one meaning, for example, **well**, **base**, **conduct**, **step**, **classes**, and **property**. Have students locate each word in the text. Provide two common meanings of the term. Have students choose the meaning of the term as it is used in the text. For example, a **well** can be a shaft or enclosed hole, or it can mean that someone is in good health. In the activity, **well** is an enclosed hole in a well plate.
Perform an Activity: Testing Aspirin

OVERALL EXPECTATIONS: A1, C1, C2, C3

SPECIFIC EXPECTATIONS
Scientific Investigation Skills: A1.5, A1.10
Relating Science to Technology, Society, and the Environment: C1.1
Developing Skills of Investigation and Communication Skills: C2.1, C2.6, C2.7
Understanding Basic Concepts: C3.4, C3.5

The full Overall and Specific Expectations are listed on pages 183–185.

KEY CONCEPTS
- Chemical reactions involving household products have intended and unintended effects.
- Many consumer products involve chemical reactions.
- There are several types of chemical reactions.

EVIDENCE OF LEARNING
- Look for evidence that students can:
  - follow instructions, and observe and record results
  - draw conclusions based on observed data

SCIENCE BACKGROUND
- Reduced acidity Aspirin is often called "buffered" Aspirin. The buffer is a base such as magnesium oxide, magnesium carbonate, calcium carbonate, or a combination of more than one base. The calcium carbonate works by neutralizing some of the acid in the stomach.
- Aspirin can be in two different forms in the body. This is because it changes from a fat-soluble substance in an acidic solution (such as in the stomach) to a watersoluble substance as the pH of the solution becomes neutral or basic. When acetylsalicylic acid enters the stomach, its fat-soluble form passes through the stomach lining and into the body. The higher pH outside the stomach walls causes the acetylsalicylic acid to become water soluble, so it cannot pass through the stomach walls and back into the stomach.

TEACHING NOTES

Student Safety
- Sodium hydroxide is corrosive, so tell students to report any spills immediately and wash skin or fabrics with water.
- Students with known Aspirin or NSAID (Non-Steroidal Anti-Inflammatory Drugs) allergies must avoid contact with the medications.
• Have students work in small groups for this activity.

**Purpose**
• This activity will help students understand the chemical differences between Aspirin and reduced-acidity Aspirin.

**Equipment and Materials**
• Before class, gather the materials and set up a workstation for each group.
• Use a 0.1M solution of sodium hydroxide.
• In place of a glass-marking pen, you can use tape to label the flasks. In place of a mortar and pestle, crush the tablet between waxed paper using the bowl of a spoon.

**Procedure**
• For Step 2, students may use a stirring stick to reduce spills.
• For Step 8, have students use tally marks to count the number of drops of sodium hydroxide used.
• Distribute BLM 6.7-1 Perform an Activity: Testing Aspirin to help students record their observations.

**Analyze and Evaluate**
(a) Sample answer: Regular Aspirin took 74 drops; reduced-acidity Aspirin took 52 drops.
(b) Sample answer: It shows that reduced-acidity Aspirin is less acidic.
(c) Sample answer: Losing some of the powder when the tablets were crushed may have led to inaccuracy. The size of the drops may have led to inaccuracy.

**Apply and Extend**
(d) Sample answer: Reduced-acidity Aspirin will be less damaging to the digestive system.
(e) Answers will vary. The presentations should reflect students’ findings, such as: Aspirin is used to prevent heart attacks and strokes because it interferes with the blood’s ability to clot. It is also a pain reliever and anti-inflammatory. Risks include allergic reactions, kidney failure, ulcers, liver damage, hearing loss, and gastrointestinal bleeding.

**DIFFERENTIATED INSTRUCTION**
• Verbal students may read aloud the instructions, kinesthetic students can perform the procedure, and visual students may decide when to stop adding sodium hydroxide.

**LITERACY TIPS AND ENGLISH LANGUAGE LEARNERS**
• Have English language learners read through the steps of the activity aloud with a partner, to ensure they understand the procedure.
Which Antacid is more effective? (Adapted from Nelson Science Connections 10, Teacher’s Resources, 2011)

**EVIDENCE OF LEARNING**

Look for evidence that students can:
- formulate a hypothesis about the effectiveness of antacid
- design a procedure to test the effectiveness of an antacid
- carry out the procedure
- analyze and communicate the results of the procedure

**SCIENCE BACKGROUND**

**Antacid Compounds**
- All fast-acting antacids contain bases. However, different antacids contain different bases: Some contain calcium carbonate; these antacids are often also marketed as calcium supplements. Some other antacids contain hydroxides of aluminum and/or magnesium. Most antacids also contain sweeteners, natural and/or artificial flavourings, and fillers.
- Antacids are typically sold in solid tablet or liquid form. Both forms of antacid contain the same active ingredients (CaCO₃, Mg(OH)₂, or Al(OH)₃). The difference in state is due to differences in other ingredients.
- Some antacids also contain simethicone or other similar compounds. These compounds can help to reduce the feeling of gassiness or bloating that can accompany indigestion.
- Extra-strength antacids typically contain the same ingredients as regular-strength antacids; extra-strength preparations simply contain a larger amount of the active ingredient.

**Acid Suppressors**
- Until recently, the only treatment for heartburn was fast-acting antacids. Today, there are a variety of prescription and over-the-counter treatments that can prevent heartburn. These drugs include omeprazole, cimetidine, and pantoprazole.
- Instead of reacting with and neutralizing the acid in the stomach, these acid suppressors prevent the stomach from producing excess acid in the first place.
TEACHING NOTES

Student Safety
- Hydrochloric acid and sodium hydroxide can cause burns and can severely damage the eyes. Students should wear gloves, aprons, and goggles at all times while handling hydrochloric acid and sodium hydroxide. Spills should be wiped up immediately with wet paper towels. If students spill acid or hydroxide on themselves, they should immediately rinse the area with copious amounts of running water.
- Although antacid tablets are designed to be eaten, students should not eat anything in the lab.

Testable Question
- Have students brainstorm different ways of defining effectiveness. For example, one group might say that the most effective antacid neutralizes the greatest volume of acid; another group might say that the most effective antacid neutralizes a given amount of acid in the shortest amount of time. Have students work in groups to identify the definition that can most readily be tested in the conditions they are working under.
- If necessary, review with students the definition of neutralization reaction and discuss what happens to pH as a base is added to an acid.

Hypothesis/Prediction
- Sample prediction: I think the name-brand antacid will neutralize more hydrochloric acid than the generic antacid.

Equipment and Materials
- Liquid antacid can also be used for this experiment. If students use liquid antacid, they should use equal volumes of the two types.
- Make sure students are using fast-acting antacids containing calcium carbonate, magnesium hydroxide, or aluminum hydroxide. They should not use antacids that contain anti-gas products or acid reducers or suppressors.
- For this experiment to be properly controlled, the antacids students test should have the same active ingredient. Ideally, the antacids should be the same flavour and advertised strength.

Experimental Design
- As students think about procedures for Part B, remind them that their goal is to determine how much acid each antacid tablet can neutralize. Students should work in groups to identify variables to control during Part B.

Procedure
- Students’ data tables can take various forms. However, their tables should, at the minimum, provide space for them to record the color of the solution at each step and the amounts of acid, antacid, and base added to the solution.
- Make sure students add the same volume of acid to both antacid solutions. To ensure that both solutions contain excess acid, you may wish to have students add an extra millilitre of acid to the first solution after it turns red, and then add that a millilitre of acid to the second solution as well.
• If students' solutions turn yellow again after they stand for 10 minutes, students should add another millilitre of acid to each flask and let it stand again for 10 minutes. They should continue to do this until the solution remains red after 10 minutes.

• Sample Student Procedure for Part B:
  1. Put on safety goggles, an apron, and gloves.
  2. Record the initial colour of each antacid/acid solution.
  3. Add one drop of sodium hydroxide solution to the first antacid solution. 
     Swirl the solution to mix it well.
  4. Record any colour change in the solution.
  5. Repeat steps 2 and 3 just until the solution turns yellow.
  6. Record the number of drops of base added to the solution.
  7. Repeat steps 2–5 for the second antacid solution.

**Analyze and Evaluate**

(a) Sample answer: When the acid was added to the solution, the solution turned red. The solution turned red because I added more acid than the antacid tablet could neutralize. The excess acid made the solution acidic. Methyl orange indicator turns red in acidic solutions.

(b) The change that told me that the solution had been neutralized was that the color changed from red to yellow.

(c) \( \text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O} \)

(d) Sample answer: Both antacids are equally effective. It took the same amount of sodium hydroxide to neutralize both solutions. That shows that the amount of excess acid left in the solutions was the same. Since I added the same amount of acid to both solutions, both antacids must have neutralized the same amount of acid.

**DIFFERENTIATED INSTRUCTION**

• Visual learners may benefit from drawing or viewing diagrams to represent each step in the procedure.

• Interpersonal learners and other students can discuss the procedural steps with each other to ensure understanding.

**LITERACY TIPS AND ENGLISH LANGUAGE LEARNERS**

• Have English language learners and struggling readers read the procedure carefully and identify any terms, phrases, or instructions they do not understand. Have students work in pairs to clarify the meaning of anything they do not understand. To ensure that all students understand the procedure and the appropriate safety precautions, review students’ discussions with them before allowing them to proceed.
Appendix C: Performance Task - Lab Data Sheets

Properties of Acids and Bases (adapted from Nelson Science Connections 10, Teacher’s Resources, 2011)

Blackline Master 5.9-1

Name: ___________________________ Date: ___________________________

Perform an Activity: Properties of Acids and Bases

1. Record your step-by-step procedure for each of these tests.
   (i) electrical conductivity

   ___________________________
   ___________________________
   ___________________________
   ___________________________

   (ii) reaction with magnesium

   ___________________________
   ___________________________
   ___________________________
   ___________________________

   (iii) reaction with sodium hydrogen carbonate

   ___________________________
   ___________________________
   ___________________________
   ___________________________

   (iv) colour with bromothymol blue indicator

   ___________________________
   ___________________________
   ___________________________
   ___________________________

   (v) effect on red and blue litmus paper

   ___________________________
   ___________________________
   ___________________________
   ___________________________
Perform an Activity: Properties of Acids and Bases (continued)

Use the following table to record your observations for both Part A and Part B. If you test more than two unknown solutions, place your observations on another piece of paper.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>electrical conductivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reaction with magnesium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reaction with sodium hydrogen carbonate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>colour with bromothymol blue indicator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>effect on red and blue litmus paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Make sure you answer the Analyze and Evaluate and Apply and Extend questions in your textbook.
Perform an Activity: Testing Aspirin

Use the following tables to record your observations. Remember to stop adding drops of sodium hydroxide when the colour stops changing. Record the total number of drops of sodium hydroxide you added to each flask.

**Table 1 Aspirin**

<table>
<thead>
<tr>
<th>Amount of sodium hydroxide</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>drops 1–10</td>
<td></td>
</tr>
<tr>
<td>drops 11–20</td>
<td></td>
</tr>
<tr>
<td>drops 21–30</td>
<td></td>
</tr>
<tr>
<td>drops 31–40</td>
<td></td>
</tr>
<tr>
<td>drops 41–50</td>
<td></td>
</tr>
<tr>
<td>drops 51–60</td>
<td></td>
</tr>
<tr>
<td>drops 61–70</td>
<td></td>
</tr>
<tr>
<td>drops 71–80</td>
<td></td>
</tr>
<tr>
<td>drops 81–90</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2 Reduced-acidity Aspirin**

<table>
<thead>
<tr>
<th>Amount of sodium hydroxide</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>drops 1–10</td>
<td></td>
</tr>
<tr>
<td>drops 11–20</td>
<td></td>
</tr>
<tr>
<td>drops 21–30</td>
<td></td>
</tr>
<tr>
<td>drops 31–40</td>
<td></td>
</tr>
<tr>
<td>drops 41–50</td>
<td></td>
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<tr>
<td>drops 51–60</td>
<td></td>
</tr>
<tr>
<td>drops 61–70</td>
<td></td>
</tr>
<tr>
<td>drops 71–80</td>
<td></td>
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<tr>
<td>drops 81–90</td>
<td></td>
</tr>
</tbody>
</table>
Measuring pH of Household Acids and Bases

Many common household solutions contain acids and bases. Acid-base indicators, such as litmus and red cabbage juice, turn different colors in acidic and basic solutions. They can, therefore, be used to show if a solution is acidic or basic. An acid turns blue litmus paper red, and a base turns red litmus paper blue. The acidity of a solution can be expressed using the pH scale. Acidic solutions have pH values less than 7, basic solutions have pH values greater than 7, and neutral solutions have a pH value equal to 7.

In this experiment, you will use litmus and a computer-interfaced pH Sensor to determine the pH values of household substances. After adding red cabbage juice to the same substances, you will determine the different red cabbage juice indicator colors over the entire pH range.

Objectives
In this experiment, you will:
- Use litmus paper and a pH Sensor to determine the pH values of household substances.
- Add cabbage juice to the same substances and determine different red cabbage juice indicator colors over the entire pH range.

Materials

- computer
- Vernier computer interface
- Logger Pro
- Vernier pH Sensor
- wash bottle
- distilled water
- ring stand
- utility clamp
- sensor soaking solution
- household solutions
- 7 small test tubes
- test-tube rack
- red and blue litmus paper
- paper towel
- stirring rod
- red cabbage juice
- 250 mL beaker

Procedure

1. Obtain and wear goggles. **CAUTION:** Do not eat or drink in the laboratory.

Part I: Litmus Tests

2. Label 7 test tubes with the numbers 1–7 and place them in a test-tube rack.

3. Measure 3 mL of vinegar into test tube 1. Refer to the data table and fill each of the test tubes 2–7 to about the same level with its respective solution. **CAUTION:** Ammonia solution is toxic. Its liquid and vapor are extremely irritating, especially to eyes. Drain cleaner solution is corrosive. Handle these solutions with care. Do not allow the solutions to contact your skin or clothing. Wear goggles at all times. Notify your teacher immediately in the event of an accident.

4. Use a stirring rod to transfer one drop of vinegar to a small piece of blue litmus paper on a paper towel. Transfer one drop to a piece of red litmus paper on a paper towel. Record the results. Clean and dry the stirring rod each time.

5. Test solutions 2–7 using the same procedure. Be sure to clean and dry the stirring rod each time.
Part II Red Cabbage Juice Indicator

6. After you have finished the Part I litmus tests, add 3 mL of red cabbage juice indicator to each of the 7 test tubes. Record your observations. Dispose of the test-tube contents as directed by your teacher.

Part III pH Tests

7. Connect the pH Sensor to the computer interface. Prepare the computer to monitor pH by opening the file “21 Household Acids” from the *Chemistry with Vernier* folder.

8. Raise the pH Sensor from the sensor storage solution and set the solution aside. Use a wash bottle filled with distilled water to thoroughly rinse the tip of the sensor as demonstrated by your instructor. Catch the rinse water in a 250 mL beaker.

9. Get one of the 7 solutions in the small container supplied by your sensor. Raise the solution to the pH Sensor and swirl the solution about the sensor (see Figure 2). When the pH reading stabilizes, record the pH value in your data table.

10. Prepare the pH Sensor for reuse.
   a. Rinse it with distilled water from a wash bottle.
   b. Place the sensor into the sensor soaking solution and swirl the solution about the sensor briefly.
   c. Rinse with distilled water again.

11. Determine the pH of the other solutions using the Step 9 procedure. You must clean the sensor, using the Step 10 procedure, between tests. When you are done, rinse the tip of the sensor with distilled water and return it to the sensor soaking solution.

*Figure 2*
## Data Table

<table>
<thead>
<tr>
<th>Test Tube</th>
<th>Solution</th>
<th>Blue Litmus</th>
<th>Red Litmus</th>
<th>Red Cabbage Juice</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>vinegar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ammonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>lemon juice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>soft drink</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>drain cleaner</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>detergent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>baking soda</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Processing the Data

1. Which of the household solutions tested are acids? How can you tell?
2. Which of the solutions are bases? How can you tell?
3. What color(s) is red cabbage juice indicator in acids? In bases?
4. Can red cabbage juice indicator be used to determine the strength of acids and bases? Explain.
5. List advantages and disadvantages of litmus and red cabbage juice indicators.
Measuring Conductivity of Solutions

If an ionic compound is dissolved in water, it dissociates into ions and the resulting solution will conduct electricity. Dissolving solid sodium chloride in water releases ions according to the equation:

\[
\text{NaCl(s)} \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^- (\text{aq})
\]

In this experiment, you will study the effect of increasing the concentration of an ionic compound on conductivity. Conductivity will be measured as concentration of the solution is gradually increased by the addition of concentrated NaCl drops. The same procedure will be used to investigate the effect of adding solutions with the same concentration (1.0 M), but different numbers of ions in their formulas: aluminum chloride, AlCl₃, and calcium chloride, CaCl₂. A computer-interfaced Conductivity Probe will be used to measure conductivity of the solution. Conductivity is measured in microsiemens per centimeter (µS/cm).

Objectives

In this experiment, you will

- Use a Conductivity Probe to measure the conductivity of solutions.
- Investigate the relationship between the conductivity and concentration of a solution.
- Investigate the conductivity of solutions resulting from compounds that dissociate to produce different number of ions.

Materials

- computer
- Vernier computer interface
- Logger Pro
- Vernier Conductivity Probe
- ring stand
- utility clamp
- wash bottle
- distilled water
- 100 mL beaker
- 1.0 M NaCl solution
- 1.0 M CaCl₂ solution
- 1.0 M AlCl₃ solution
- stirring rod
- tissue
Procedure

1. Obtain and wear goggles.

2. Your experiment setup should look like Figure 3. The Conductivity Probe is already attached to the interface. It should be set on the 0–2000 µS/cm position.

3. Prepare the computer for data collection by opening the file “14 Conductivity Solutions” from the Chemistry with Vernier folder.

4. Add 70 mL of distilled water to a clean 100 mL beaker. Obtain a dropper bottle that contains 1.0 M NaCl solution.

5. Before adding any drops of solution:
   a. Click .
   b. Carefully raise the beaker and its contents up around the Conductivity Probe until the hole near the probe end is completely submerged in the solution being tested. Important: Since the two electrodes are positioned on either side of the hole, this part of the probe must be completely submerged.
   c. Monitor the conductivity of the distilled water until the conductivity reading stabilizes.
   d. Click , and then lower the beaker away from the probe. Type 0 in the edit box (for 0 drops added). Press the ENTER key to store this data pair. This gives the conductivity of the water before any salt solution is added.

6. You are now ready to begin adding salt solution.
   a. Add 1 drop of NaCl solution to the distilled water. Stir to ensure thorough mixing.
   b. Raise the beaker until the hole near the probe end is completely submerged in the solution. Swirl the solution briefly.
   c. Monitor the conductivity of the solution until the reading stabilizes.
   d. Click , and then lower the beaker away from the probe. Type 1 (the total drops added) in the edit box and press ENTER.

7. Repeat the Step 6 procedure, entering 2 this time.

8. Continue this procedure, adding 1-drop portions of NaCl solution, measuring conductivity, and entering the total number of drops added—until a total of 8 drops have been added.

9. Click when you have finished collecting data. Dispose of the beaker contents as directed by your teacher. Rinse the probe tip with distilled water from a wash bottle. Carefully blot the probe dry with a tissue.

10. Prepare the computer for data collection. From the Experiment menu, choose Store Latest Run. This stores the data so it can be used later, but it will be still be displayed while you do your second and third trials.

11. Repeat Steps 4–10, this time using 1.0 M AlCl3 solution in place of 1.0 M NaCl solution.

12. Repeat Steps 4–9, this time using 1.0 M CaCl2 solution.

13. Click on the Linear Fit button, . Be sure all three data runs are selected, then click . A best-fit linear regression line will be shown for each of your three runs. In your data table,
record the value of the slope, \( m \), for each of the three solutions. (The linear regression statistics are displayed in a floating box for each of the data sets.)

14. To print a graph of concentration vs. volume showing all three data runs:
   a. Label all three curves by choosing Text Annotation from the Insert menu, and typing “sodium chloride” (or “aluminum chloride”, or “calcium chloride”) in the edit box. Then drag each box to a position near its respective curve.
   
b. Print a copy of the graph, with all three data sets and the regression lines displayed. Enter your name(s) and the number of copies of the graph you want.

Data Table

<table>
<thead>
<tr>
<th>Solution</th>
<th>Slope, ( m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 M NaCl</td>
<td></td>
</tr>
<tr>
<td>1.0 M AlCl₃</td>
<td></td>
</tr>
<tr>
<td>1.0 M CaCl₂</td>
<td></td>
</tr>
</tbody>
</table>

Processing the Data

1. Describe the appearance of each of the three curves on your graph.

2. Describe the change in conductivity as the concentration of the NaCl solution was increased by the addition of NaCl drops. What kind of mathematical relationship does there appear to be between conductivity and concentration?

3. Write a chemical equation for the dissociation of NaCl, AlCl₃, and CaCl₂ in water.

4. Which graph had the largest slope value? The smallest? Since all solutions had the same original concentration (1.0 M), what accounts for the difference in the slope of the three plots? Explain.
Acid-Base Titration

A titration is a process used to determine the volume of a solution needed to react with a given amount of another substance. In this experiment, you will titrate hydrochloric acid solution, HCl, with a basic sodium hydroxide solution, NaOH. The concentration of the NaOH solution is given and you will determine the unknown concentration of the HCl. Hydrogen ions from the HCl react with hydroxide ions from the NaOH in a one-to-one ratio to produce water in the overall reaction:

$$\text{H}^+(aq) + \text{Cl}^-(aq) + \text{Na}^+(aq) + \text{OH}^- (aq) \rightarrow \text{H}_2\text{O}(l) + \text{Na}^+(aq) + \text{Cl}^-(aq)$$

When an HCl solution is titrated with an NaOH solution, the pH of the acidic solution is initially low. As base is added, the change in pH is quite gradual until close to the equivalence point, when equimolar amounts of acid and base have been mixed. Near the equivalence point, the pH increases very rapidly, as shown in Figure 4. The change in pH then becomes more gradual again, before leveling off with the addition of excess base.

In this experiment, you will use a computer to monitor pH as you titrate. The region of most rapid pH change will then be used to determine the equivalence point. The volume of NaOH titrant used at the equivalence point will be used to determine the molarity of the HCl.

![Acid-Base Titration](image)

**Figure 4**

**Objectives**

In this experiment, you will

- Use a pH Sensor to monitor changes in pH as sodium hydroxide solution is added to a hydrochloric acid solution.
- Plot a graph of pH vs. volume of sodium hydroxide solution added.
- Use the graph to determine the equivalence point of the titration.
- Use the results to calculate the concentration of the hydrochloric acid solution.
Materials for both Method 1 (buret) and Method 2 (Drop Counter)
- computer
- Vernier computer interface
- Logger Pro
- Vernier pH Sensor
- HCl solution, unknown concentration
- ~0.1 M NaOH solution
- pipet bulb or pump
- magnetic stirrer (if available)
- stirring bar or Microstirrer (if available)
- wash bottle
- distilled water
- ring stand
- 1 utility clamp
- 250 mL beaker

Materials required only for Method 1 (buret)
- 50 mL burette
- 10 mL pipette
- 2nd utility clamp
- 2nd 250 mL beaker

Materials required only for Method 2 (Drop Counter)
- Vernier Drop Counter
- 60 mL reagent reservoir
- 5 mL pipette or graduated 10 mL pipette
- 100 mL beaker
- 10 mL graduated cylinder

Choosing a Method
Method 1 has the student deliver volumes of NaOH titrant from a burette. After titrant is added, and pH values have stabilized, the student is prompted to enter the burette reading manually and a pH-volume data pair is stored.

Method 2 uses a Vernier Drop Counter to take volume readings. NaOH titrant is delivered drop by drop from the reagent reservoir through the Drop Counter slot. After the drop reacts with the reagent in the beaker, the volume of the drop is calculated, and a pH-volume data pair is stored.
METHOD 1: Measuring Volume Using a Burette

1. Obtain and wear goggles.

2. Add 50 mL of distilled water to a 250 mL beaker. Use a pipette bulb (or pipette pump) to pipette 10.0 mL of the HCl solution into the distilled water in the 250 mL beaker. **CAUTION:** Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.

3. Place the beaker on a magnetic stirrer and add a stirring bar. If no magnetic stirrer is available, you need to stir with a stirring rod during the titration.

4. Use a utility clamp to suspend a pH Sensor on a ring stand as shown in Figure 5. Position the pH Sensor in the HCl solution and adjust its position so it will not be struck by the stirring bar. Turn on the magnetic stirrer, and adjust it to a medium stirring rate (with no splashing of solution).

5. Obtain approximately 60 mL of ~0.1 M NaOH solution in a 250 mL beaker. Obtain a 50 mL burette and rinse the burette with a few mL of the ~0.1 M NaOH solution. Use a utility clamp to attach the burette to the ring stand as shown here. Fill the burette a little above the 0.00 mL level of the burette with ~0.1 M NaOH solution. Drain a small amount of NaOH solution into the beaker so it fills the burette tip and leaves the NaOH at the 0.00 mL level of the burette.

   Record the precise concentration of the NaOH solution in your data table. Dispose of the waste solution from this step as directed by your teacher. **CAUTION:** Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing.

6. Connect the pH Sensor to the computer interface. Prepare the computer for data collection by opening the file “24a Acid-Base Titration” from the Chemistry with Vernier folder. Check to see that the pH value is between 2 and 3.

7. Before adding NaOH titrant, click \[ \text{Collect} \] and monitor pH for 5-10 seconds. Once the displayed pH reading has stabilized, click \[ \text{Keep} \]. In the edit box, type “0” (for 0 mL added). Press the ENTER key or click \[ \text{OK} \] to store the first data pair for this experiment.

8. You are now ready to begin the titration. This process goes faster if one person manipulates and reads the buret while another person operates the computer and enters volumes.

   a. Add the next increment of NaOH titrant (enough to raise the pH about 0.15 units). When the pH stabilizes, again click \[ \text{Keep} \]. In the edit box, type the current buret reading, to the nearest 0.01 mL. Press ENTER or click \[ \text{OK} \]. You have now saved the second data pair for the experiment.

   b. Continue adding NaOH solution in increments that raise the pH by about 0.15 units and enter the burette reading after each increment. Proceed in this manner until the pH is 3.5.

   c. When a pH value of approximately 3.5 is reached, change to a one-drop increment. Enter a new burette reading after each increment. Note: It is important that all increment volumes in this part of the titration be equal; that is, one-drop increments.

   d. After a pH value of approximately 10 is reached, again add larger increments that raise the pH by about 0.15 pH units, and enter the burette level after each increment.

   e. Continue adding NaOH solution until the pH value remains constant.

9. When you have finished collecting data, click \[ \text{Stop} \]. Dispose of the beaker contents as directed by your teacher.
10. Print copies of the table and the graph.
11. If time permits, repeat the procedure.

**METHOD 2: Measuring Volume with a Drop Counter**

![Figure 6](image)

1. Obtain and wear goggles.
2. Connect the pH Sensor to CH 1 of the computer interface. Lower the Drop Counter onto a ring stand and connect its cable to DIG/SONIC 1.
3. Add 40 mL of distilled water to a 100 mL beaker. Use a pipet bulb (or pipet pump) to pipet 5.00 mL of the HCl solution into the 100 mL beaker with distilled water. **CAUTION:** Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.
4. Obtain approximately 40 mL of ~0.1 M NaOH solution in a 250 mL beaker. Record the precise NaOH concentration in your data table. **CAUTION:** Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing.
5. Obtain the plastic 60 mL reagent reservoir. **Note:** The bottom valve will be used to open or close the reservoir, while the top valve will be used to finely adjust the flow rate. For now, close both valves by turning the handles to a horizontal position.

   Rinse it with a few mL of the ~0.1 M NaOH solution. Use a utility clamp to attach the reagent reservoir to the ring stand. Add the remainder of the NaOH solution to the reagent reservoir.

   Drain a small amount of NaOH solution into the 250 mL beaker so it fills the reservoir’s tip. To do this, turn both valve handles to the vertical position for a moment, then turn them both back to horizontal.
6. Prepare the computer for data collection by opening the file “24b Acid-Base (Drop Count)” from the *Chemistry with Computers* folder. Check to see that the pH value is between 1.5 and 2.5.
7. To calibrate drops so that a precise volume of titrant is recorded in units of milliliters:
a. From the Experiment menu, choose Calibrate DIG 1: Drop Counter (mL).
b. Proceed by one of these two methods:
   - If you have previously calibrated the drop size of your reagent reservoir and want to continue with the same drop size, select the Manual button, enter the number of Drops / mL, and click OK. Then proceed directly to Step 8.
   - If you want to perform a new calibration, select the Automatic button, and continue with Step c below.
c. Place a 10 mL graduated cylinder directly below the slot on the Drop Counter, lining it up with the tip of the reagent reservoir.
d. Open the bottom valve on the reagent reservoir (vertical). Keep the top valve closed (horizontal).
e. Click the Start button.
f. Slowly open the top valve of the reagent reservoir so that drops are released at a slow rate (~1 drop every two seconds). You should see the drops being counted on the computer screen.
g. When the volume of NaOH solution in the graduated cylinder is between 9 and 10 mL, close the bottom valve of the reagent reservoir.
h. Enter the precise volume of NaOH (read to the nearest 0.1 mL) in the edit box. Record the number of Drops / mL displayed on the screen for possible future use.
i. Click OK. Discard the NaOH solution in the graduated cylinder as indicated by your instructor and set the graduated cylinder aside.

8. Assemble the apparatus.
   a. Place the magnetic stirrer on the base of the ring stand.
   b. Insert the pH Sensor through the large hole in the Drop Counter.
   c. Attach the Microstirrer to the bottom of the pH Sensor, as shown in Figure 6. Rotate the paddle wheel of the Microstirrer and make sure that it does not touch the bulb of the pH Sensor.
   d. Adjust the positions of the Drop Counter and reagent reservoir so they are both lined up with the center of the magnetic stirrer.
   e. Lift up the pH Sensor, and slide the beaker containing the HCl solution onto the magnetic stirrer. Lower the pH Sensor into the beaker.
   f. Adjust the position of the Drop Counter so that the Microstirrer on the pH Sensor is just touching the bottom of the beaker.
   g. Adjust the reagent reservoir so its tip is just above the Drop Counter slot.

9. Turn on the magnetic stirrer so that the Microstirrer is stirring at a fast rate.

10. You are now ready to begin collecting data. Click Collect. No data will be collected until the first drop goes through the Drop Counter slot. Fully open the bottom valve—the top valve should still be adjusted so drops are released at a rate of about 1 drop every 2 seconds. When the first drop passes through the Drop Counter slot, check the data table to see that the first data pair was recorded.

11. Continue watching your graph to see when a large increase in pH takes place—this will be the equivalence point of the reaction. When this jump in pH occurs, let the titration proceed for several more milliliters of titrant, then click Stop. Turn the bottom valve of the reagent reservoir to a closed (horizontal) position.
12. Dispose of the beaker contents as directed by your teacher.
13. Print copies of the table.
14. Print copies of the graph.
15. If time permits, repeat the procedure.

**Processing the Data**

1. Use your graph and data table to determine the volume of NaOH titrant used in each trial. Examine the data to find the largest increase in pH values upon the addition of 1 drop of NaOH solution. Find and record the NaOH volume just before and after this jump.

2. Determine the volume of NaOH added at the equivalence point. To do this, add the two NaOH values determined above and divide by two.

3. Calculate the number of moles of NaOH used.

4. Using the equation for the neutralization reaction given in the introduction, determine the number of moles of HCl used.

5. Calculate the HCl concentration using the volume of unknown HCl you pipeted out for each titration.

6. (Optional) If you did two titrations, determine the average [HCl] in mol/L.

**DATA TABLE**

<table>
<thead>
<tr>
<th>Concentration of NaOH</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOH volume added <em>before</em> the largest pH increase</td>
<td>mL</td>
<td>mL</td>
</tr>
<tr>
<td>NaOH volume added <em>after</em> the largest pH increase</td>
<td>mL</td>
<td>mL</td>
</tr>
<tr>
<td>Volume of NaOH added at equivalence point</td>
<td>mL</td>
<td>mL</td>
</tr>
<tr>
<td>Moles NaOH</td>
<td>Mol</td>
<td>Mol</td>
</tr>
<tr>
<td>Moles HCl</td>
<td>Mol</td>
<td>Mol</td>
</tr>
<tr>
<td>Concentration of HCl</td>
<td>Mol/L</td>
<td>Mol/L</td>
</tr>
<tr>
<td>Average [HCl]</td>
<td>Mol/L</td>
<td>Mol/L</td>
</tr>
</tbody>
</table>
Appendix E: Perform an Activity Self-Assessment Checklist
Properties of Acids and Bases and Testing Aspirin Activities (Adapted from Nelson Science Connections 10, Teacher’s Resources, 2011).

Self-Assessment Checklist 2: Perform an Activity

<table>
<thead>
<tr>
<th>Name: __________________________</th>
<th>Date: __________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title: __________________________</td>
<td>Section number: __________________</td>
</tr>
</tbody>
</table>

Check the level of understanding for each criterion, and make comments as needed. Not all criteria or categories will fit every activity.

1. I was unable to ....
2. I needed help to ....
3. I was usually able to ....
4. It was easy for me to ....

<table>
<thead>
<tr>
<th>Knowledge and Understanding</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>* understand the task at hand</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>Thinking and Investigation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>* select and use equipment with concern for safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* make complete and precise observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* display the numerical data in tables and charts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* record the qualitative data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* look for patterns in the data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>* use the vocabulary and terminology of the chapter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* express ideas that supported my conclusion</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>* communicate the steps of the experimental procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* make accurate and complete graphs and tables based on the data</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>* list potential applications of the activity to real-world situations</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>* suggest extensions to the activity</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Appendix F: Design Your Investigation Self-Assessment Checklist
Which Antacid is more effective? (Adapted from Nelson Science Connections 10, Teacher’s Resources, 2011).

<table>
<thead>
<tr>
<th>Knowledge and Understanding</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>name and write the formulas of acids and bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>write the chemical equation for a neutralization reaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thinking and Investigation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>plan and develop a fair test of the effectiveness of the antacids</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>design and conduct a safe investigation</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>record observations with accuracy and organization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>analyze the results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>prepare a complete lab report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compare the effectiveness of the two antacids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>demonstrate an understanding of the role of chemical reactions in the use of antacids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compare the effectiveness of generic and brand-name antacid products containing the same active ingredient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix G: Perform an Activity Assessment Rubric

Properties of Acids and Bases and Testing Aspirin Activities (adapted from Nelson Science Connections 10, Teacher’s Resources, 2011).

<table>
<thead>
<tr>
<th>Categories and Criteria</th>
<th>Knowledge and Understanding</th>
<th>Thinking and Investigation</th>
<th>Selection and use of equipment with concern for safety</th>
<th>Making complete and precise observations</th>
<th>Presentation of numerical data in tables and charts</th>
<th>Identification of patterns in data with limited observations</th>
<th>Assessment Tools 673</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student:</td>
<td>demonstrates limited understanding of content</td>
<td>selects and uses equipment with considerable appropriateness</td>
<td>selects and uses equipment with considerable concern for safety</td>
<td>regularly makes complete and precise observations</td>
<td>presents numerical data with limited accuracy</td>
<td>identifies patterns in the data with some effectiveness</td>
<td>(continued)</td>
</tr>
<tr>
<td>Knowledge and Understanding</td>
<td>demonstrates limited understanding of content</td>
<td>selects and uses equipment with considerable appropriateness</td>
<td>selects and uses equipment with considerable concern for safety</td>
<td>regularly makes complete and precise observations</td>
<td>presents numerical data with limited accuracy</td>
<td>identifies patterns in the data with some effectiveness</td>
<td>(continued)</td>
</tr>
<tr>
<td>Thinking and Investigation</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>(continued)</td>
</tr>
<tr>
<td>Selection and use of equipment with concern for safety</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>(continued)</td>
</tr>
<tr>
<td>Making complete and precise observations</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>(continued)</td>
</tr>
<tr>
<td>Presentation of numerical data in tables and charts</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>(continued)</td>
</tr>
<tr>
<td>Identification of patterns in data with limited observations</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>demonstrates some understanding of content</td>
<td>(continued)</td>
</tr>
</tbody>
</table>

*Copyright © 2011 by Nelson Education Ltd.*
### Assessment Rubric 6: Perform an Activity (continued)

<table>
<thead>
<tr>
<th>Categories and Criteria</th>
<th>50–59 % (Level 1)</th>
<th>60–69 % (Level 2)</th>
<th>70–79 % (Level 3)</th>
<th>80–100 % (Level 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Communication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of conventions, vocabulary, and terminology</td>
<td>uses conventions, vocabulary, and terminology with limited accuracy</td>
<td>uses conventions, vocabulary, and terminology with some accuracy</td>
<td>uses conventions, vocabulary, and terminology with considerable accuracy</td>
<td>uses conventions, vocabulary, and terminology with a high degree of accuracy</td>
</tr>
<tr>
<td>Expression of ideas that support conclusions</td>
<td>expresses ideas that support conclusions with limited effectiveness</td>
<td>expresses ideas that support conclusions with some effectiveness</td>
<td>expresses ideas that support conclusions with considerable effectiveness</td>
<td>expresses ideas that support conclusions with a high degree of effectiveness</td>
</tr>
<tr>
<td>Communicating the steps of an experimental procedure</td>
<td>communicates the steps of an experimental procedure with limited effectiveness</td>
<td>communicates the steps of an experimental procedure with some effectiveness</td>
<td>communicates the steps of an experimental procedure with considerable effectiveness</td>
<td>communicates the steps of an experimental procedure with a high degree of effectiveness</td>
</tr>
<tr>
<td>Making accurate and complete graphs and tables based on the data</td>
<td>rarely makes accurate and complete graphs and tables based on the data</td>
<td>occasionally makes accurate and complete graphs and tables based on the data</td>
<td>regularly makes accurate and complete graphs and tables based on the data</td>
<td>consistently makes accurate and complete graphs and tables based on the data</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification of potential applications of the results of an activity to real-world situations</td>
<td>rarely identifies potential applications to real-world situations</td>
<td>occasionally identifies potential applications to real-world situations</td>
<td>regularly identifies potential applications to real-world situations</td>
<td>consistently identifies potential applications to real-world situations</td>
</tr>
<tr>
<td>Suggesting extensions of the activity</td>
<td>suggests extensions of the activity with limited effectiveness</td>
<td>suggests extensions of the activity with some effectiveness</td>
<td>suggests extensions of the activity with considerable effectiveness</td>
<td>suggests extensions of the activity with a high degree of effectiveness</td>
</tr>
</tbody>
</table>
# Technology-Enhanced Inquiry-Based Chemistry Unit

## Assessment Summary 6: Perform an Activity

**Name:** __________________________  **Date:** __________________________

**Title:** __________________________  **Section number:** __________________________

Check the level of understanding for each criterion, and make comments as needed. *Not all criteria or categories will fit every activity.*

1. Below the provincial standard of achievement
2. Approaching the provincial standard of achievement
3. Meets the provincial standard of achievement
4. Beyond the provincial standard of achievement

<table>
<thead>
<tr>
<th>Knowledge and Understanding</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Understanding of content</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thinking and Investigation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Selection and use of equipment</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Selection and use of equipment with concern for safety</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Making complete and precise observations</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Presentation of numerical data in tables and charts</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Recording of qualitative data</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Identification of patterns in data</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Use of conventions, vocabulary, and terminology</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Expression of ideas that support conclusions</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Communicating the steps of an experimental procedure</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Making accurate and complete graphs and tables based on the data</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Identification of potential applications to real-world situations</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Suggesting extensions of the activity</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix H: Conduct an Investigation Assessment Rubric
Which Antacid is more effective? (Adapted from Nelson Science Connections 10, Teacher’s Resources, 2011)
### Assessment Rubric: Conduct an Investigation (continued)

<table>
<thead>
<tr>
<th>Categories and Criteria</th>
<th>90-93 (Level 5)</th>
<th>80-89 (Level 4)</th>
<th>70-79 (Level 3)</th>
<th>60-69 (Level 2)</th>
<th>50-59 (Level 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evaluation of the Experimental Procedure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifying potential sources of error</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making recommendations for improving the design and/or procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicating the steps of an experimental procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expressing ideas that support conclusions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicating ideas with considerable effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses conventions, vocabulary, and terminology with limited accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicates ideas with limited effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### End of Document
# Unit C Task Assessment Summary: Comparing Antacids

**Name:**

**Date:**

**Title:**

**Section number:**

Check the level of understanding for each criterion, and make comments as needed. *Not all criteria or categories will fit every activity.*

1. Below the provincial standard of achievement
2. Approaching the provincial standard of achievement
3. Meets the provincial standard of achievement
4. Beyond the provincial standard of achievement

<table>
<thead>
<tr>
<th>Knowledge and Understanding</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Naming and writing the formulas of acids and bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Writing the chemical equation for a neutralization reaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thinking and Investigation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Planning and development of a fair test of the effectiveness of the antacids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Designing and conducting a safe investigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Recording observations with accuracy and organization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Analysis of the results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preparation of a complete lab report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Comparison of the effectiveness of the two antacids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Demonstrate an understanding of the role of chemical reactions in the use of antacids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Comparison of the effectiveness of generic and brand-name antacid products containing the same active ingredient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix I: Presentation Assessment Rubric (Adapted from Applied Technology High School, UAE, 2011)

<table>
<thead>
<tr>
<th>Assessment Rubric: Presentation</th>
<th>Content</th>
<th>Accuracy</th>
<th>Sequencing of Information</th>
<th>Use of Graphics</th>
<th>Mechanics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Categories and Criteria</strong></td>
<td>80-100% (level 4)</td>
<td>70-79% (level 3)</td>
<td>60-69% (level 2)</td>
<td>50-59% (level 1)</td>
<td></td>
</tr>
<tr>
<td>50-59% (level 1)</td>
<td>The presentation addresses most of the required content.</td>
<td>The content is generally accurate, but one piece of information is clearly inaccurate.</td>
<td>There is no clear plan for the organization of information.</td>
<td>Several graphics are unattractive AND detract from the content of the presentation.</td>
<td>The presentation contains several errors in language and mechanics, but is still understandable.</td>
</tr>
<tr>
<td>60-69% (level 2)</td>
<td>The presentation addresses a limited amount of the required content.</td>
<td>The content is generally accurate, but one piece of information is out of place.</td>
<td>Several graphics are unattractive AND detract from the content of the presentation.</td>
<td>All graphics are not attractive but still support the topic of the presentation.</td>
<td>Project contains a few minor errors in language and mechanics.</td>
</tr>
<tr>
<td>70-79% (level 3)</td>
<td>The presentation addresses all of the required content.</td>
<td>Most information is organized in a clear, logical way.</td>
<td>One slide or piece of information seems out of place.</td>
<td>A few graphics are attractive (size and color) and support the topic of the presentation.</td>
<td>Project contains no language or mechanics errors.</td>
</tr>
<tr>
<td>80-100% (level 4)</td>
<td>All content throughout the presentation is accurate. There are no factual errors.</td>
<td>All graphics are attractive (size and color) and support the topic of the presentation.</td>
<td>It is easy to anticipate the next slide.</td>
<td>All graphics are organized in a clear, logical way.</td>
<td>The presentation contains no language or mechanics errors.</td>
</tr>
</tbody>
</table>
Appendix J: Lab Report Assessment Score Guide (Adapted from Applied Technology High School, UAE, 2011)

<table>
<thead>
<tr>
<th>Laboratory Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Title is stated as a question with correct punctuation and relates directly to topic.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Title is stated as a question with minor error in punctuation and relates directly to topic.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Title is stated as a question with punctuation errors and indirectly relates to topic.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Title is not stated as a question or has several errors in punctuation and indirectly relates to topic.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Materials</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>Materials list is complete and incudes measurements so that the experiment can be repeated.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Materials list is mostly complete and includes measurements so that the experiment can be repeated.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Materials list is incomplete incudes minimal measurements so that the experiment can be repeated.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Materials list is incomplete incudes minimal measurements so that the experiment can be repeated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Introduction</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>Well-written. Uses all proper science vocabulary to introduce topic.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Well-written. Uses some proper science vocabulary to introduce topic.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Written in basic form. Uses minimal science vocabulary to introduce topic.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Written in basic form. Does not use science vocabulary to introduce topic.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Procedure</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>All procedures are written using complete sentences in order with detailed description of steps so that lab could be repeated reliably.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Some procedures are written using complete sentences in order with detailed description of steps so that lab could be repeated reliably.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Only a few procedures are written using complete sentences in order. Written with limited description of steps so that lab would be difficult to repeat reliably.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Very few procedures are written using complete sentences in order. Written with very limited description of steps so that lab would be impossible to repeat reliably.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Data</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>All data is presented in a manner that is organized and easy to read. Data includes graphs, charts, tables, measures, etc.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Most data is presented in a manner that is organized and easy to read. Data includes graphs, charts, tables, measures, etc.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Data is present but not well-organized or incomplete.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Data is incomplete, unorganized and confusing to the reader.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Results</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>Statement of what was observed. Written in an easy to understand manner that ties observations to a conclusion.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>States some of what was observed in a manner that ties observations to a conclusion.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>States very little of what was observed in a manner that ties observations to a conclusion.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>States only a little of what was observed but not in a manner that ties observations to a conclusion.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Analysis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>Uses observations, data, vocabulary, and other evidence to create a well-supported statement showing knowledge gained.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Uses some evidence to create a statement showing knowledge gained.</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>Uses some evidence to create a statement showing knowledge gained.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Uses observations, data, vocabulary, and other evidence to create a well-supported statement showing knowledge gained.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Conclusion</strong></th>
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<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>Detailed discussion of all aspects of experiment, results, suggestions, flaws, etc. and links to other relevant science.</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Discussion of most aspects of experiment, results, suggestions, flaws, etc. but lacking links to other relevant science.</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>Discussion of some aspects of experiment, results, suggestions, flaws, etc. but lacking links to other relevant science.</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Discussion of some aspects of experiment, results, suggestions, flaws, etc. but lacking links to other relevant science.</td>
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<table>
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<tr>
<th><strong>Total Score</strong></th>
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<tbody>
<tr>
<td><strong>Comments:</strong></td>
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