

DISTANCE EDUCATION ADVANCED PLACEMENT  
CHEMISTRY 4222:  
DEVELOPMENT OF A PILOT WEB-BASED COURSE

CENTRE FOR NEWFOUNDLAND STUDIES

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**Distance Education Advanced Placement Chemistry 4222:**

**Development of a Pilot Web-based Course**

**By**

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**A project submitted to the school of Graduate  
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### ***Abstract***

This project consisted of the development of a Web-based course for the Advanced Placement (AP) Chemistry curriculum outlined by the **College Board**. The College Board is an association of schools, colleges, universities, and other educational organizations dedicated to making college courses available to all students. Through the College Board, college-level courses, including AP courses and exams, are available to students while still in high school. For further information about the College Board consult the following Internet site: <http://www.collegeboard.org/>.

The unique aspect of this project was that the AP Chemistry course was developed to be delivered from a distance, utilizing the Internet. This project involved several components, including a complete set of 72 interactive lessons, with animation, which could be accessed via the World-Wide Web. Included within each lesson were references to a textbook, study guide and a CD-ROM that accompanied the textbook. The lessons were complemented with 12 laboratory activities that were also interactive in nature, utilizing online video demonstrations. The course was developed with the support of real-time online instruction utilizing multiple party video conferencing.

This project report includes a literature review of current trends in distance education and Web course design, as well as a discussion of the final product. The challenges and limitations of designing and delivering such a course at a distance via the Internet are also addressed.

### *Acknowledgments*

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## **Introduction.**

In recent years, educators have witnessed the rapid development of computer networks, dramatic improvements in the processing power of personal computers, and striking advances in magnetic and digital storage technology. These developments have made the computer a dynamic force in distance education, providing a new and interactive means of overcoming time and distance to reach learners.

As part of ongoing research with **The Centre for TeleLearning and Rural Education, Memorial University, the Vista School district, and Stemnet**, the project of choice was the development of a Web-based course for Advanced Placement (AP) Chemistry 4222. This course was one of four courses developed for the **Vista School District Digital Intranet**. AP Chemistry 4222 was to be used in conjunction with other AP courses delivered via the Intranet: AP Math 4225, AP Physics 4224 and AP Biology 4221. This was done to determine the viability of School District Intranets for the delivery of senior high school courses from a distance.

This Web-based version of Chemistry 4222 was designed and developed in the Centre for TeleLearning and Rural Education, Faculty of Education, Memorial University of Newfoundland. The course was based on the AP Curriculum (AP Chemistry) developed by the College Board and was approved by the Department of Education for Senior High School Certification in Newfoundland and Labrador.

The College Board is an association of schools, colleges, universities, and other educational organizations dedicated to making college courses available to all students. The College Board AP courses give students an opportunity to take college-level courses

and exams while still in high school. For further information about the College Board consult the following Internet site:

<http://www.collegeboard.org/>

The primary learning resource for Chemistry 4222 is *Chemistry: Fourth edition (1997)* by Zumdahl, distributed by ITP Nelson, Scarborough, Ontario. The resource material is comprised of a textbook, a study guide and an interactive CD-ROM.

In order to view the Web pages of this project on the Internet, consult the following Internet link:

[www.stemnet.nf.ca/~vsddi](http://www.stemnet.nf.ca/~vsddi)

To gain access to the Web pages, a username of **Student** with a password of **education** must be used.

If an Internet connection is not available, Web pages may be viewed from an accompanying CD-ROM. To view the files from the CD-ROM, open the *index.htm* file in the directory **d:\apchemistry** in a Web browser such as **Netscape 4.0** or **Internet Explorer 3.2**. To view the compressed video portions of the Web pages, the plug-in **RealPlayer** is required. The RealPlayer program is available at the following Internet link:

<http://www.real.com>

Representative samples of all components of this project are included in the printed form as appendices. Since this course was designed to be viewed from the Internet using a Web browser, some of the printed pages of the appendices may not appear as they would on the computer screen.

## **Chapter 1: Rationale for Developing a Web-based Distance Education Course.**

The reasons for developing a Web-based distance education course for AP Chemistry 4222 are many. The development of district Intranet courses would serve to enhance the educational opportunities for students in remote and rural areas of the district. Such courses would be of value in rural communities that would be unable to deliver an AP program in the regular school, due to financial and/or personnel restraints. Data presented by Jones and Southern (1992) indicates that there is a significantly lower proportion of gifted education offerings in rural areas than in urban settings. With today's declining enrollments, many rural schools are faced with staffing problems. For many schools, an AP Chemistry course would be a luxury far too expensive for an already overburdened staff. The reality in rural schools is that a certain level of programming must be provided and an AP course is not an essential graduation requirement.

One of the goals of the Vista School District's **Strategic Plan, 1997-2002** states:

By 2002, technology will be incorporated and used to maximize the effectiveness of students learning, instructional management, staff development, and administration (Vista School District, 1997, p.36).

A number of strategies have been identified that would facilitate the achievement of the stated goal above. Two of these strategies were of particular interest:

- 1.2 We will evaluate the effectiveness of current distance education activities and explore new models for serving all students.

- 1.4 We will explore, through the use of technology, the development of independent study activities and courses for students.

The development of the Vista District Digital Intranet is an initiative put forth to develop these strategies to meet the stated goals, thus enhancing the educational experience for the learners of the district. Therefore, development of this Web-based course would serve to provide an opportunity for educational enrichment to rural schools of the district.

The AP curriculum is recognized world wide. The general curriculum outcomes for the AP Chemistry curriculum were developed by the College Board and are accepted nationally and internationally by major post-secondary institutions. The general curriculum outcomes for AP Chemistry may be viewed at the following Internet link:

[www.collegeboard.org/ap/chemistry](http://www.collegeboard.org/ap/chemistry)

In the province of Newfoundland and Labrador, the College Board curriculum is approved by the Department of Education for Senior High School Certification. High school students now have the opportunity to gain first-year university credit by receiving a rating of three out of five, or better, on an international College Board exam.

A distance education AP course may be of interest for both high school students and adult learners. Distant students have a variety of reasons for taking courses, including broadening their educational experience, or to smooth the transition into the post-secondary setting. By doing a variety of courses, some students hope to increase their potential career opportunities. Opportunities to diversify one's academic

background are limited in rural areas of this province.

For some adult learners, the high cost of post-secondary education may be a deterring factor which would keep them at home in a rural community, the result being, isolation from post-secondary institutions. Since these courses are offered through the Internet, the adult learner would be able to do these courses in the privacy of their own home, at their convenience. For the adult learner, this would provide the opportunity to gain high school and/or university credit. A credit could thus be gained without facing scheduling problems due to work commitments or the embarrassment of attending school with much younger students.

The distance student faces additional challenges above and beyond the normal school experience. It is not surprising that research has found that the distance students were more focused, were better time managers, and were able to work both independently and as a group member, depending on the delivery mode and location of the distance course (Gibson, 1996). Therefore, involvement in an AP course at a distance serves to develop a learner's independent study skills. Learning such skills are important since the skills are assets very much needed for success in the post-secondary setting and for life in general. As Gibson (1996) points out, with any form of distance education, if any level of success is achieved, independent study skills develop over the duration of the course. Offering a course via the Internet provides a much more flexible, yet structured, alternative to learning at a distance. This flexibility also serves to enhance the independent learner's experience.

A Web-based course also provides an opportunity to address different learning styles. In the province of Newfoundland and Labrador, the traditional mode of delivery at a distance tends to be somewhat static in that it is merely print and voice. The computer linked to the Internet provides a myriad of learning tools. The use of computer animation, digital video, simulations, animated models, as well as text and live communication, could be all integrated in living color to touch every facet of learning.

Finally, a project of this nature has its merit in that it focuses on a new and innovative approach to teaching and learning. The Internet is a relatively new and exciting medium which offers an endless number of educational opportunities. The ramifications of the Internet for education could be paralleled to advancements realized by Gutenberg's printing press. Research projects of this nature serve to expand the scope of knowledge and understanding of teaching and learning via the Internet.

**Chapter 2: Current Research Regarding the Perception of Distance Education.**

At its most basic level, distance education takes place when a teacher and student(s) are separated by physical distance, and technology (i.e., voice, video, data, and print), often in collaboration with face-to-face communication, could be used to bridge the instructional gap. Many educators ask if distance students learn as much as students that received traditional face-to-face instruction. Research comparing distance education to traditional face-to-face instruction indicates that teaching and studying at a distance could be as effective as traditional instruction, when the method and technologies used were appropriate to the instructional tasks, when there was student-to-student interaction, and when there was timely teacher-to-student feedback (Moore & Thompson, 1990; Verduin & Clark, 1991).

Achievement on various tests administered by course instructors tended to be higher for distance as opposed to traditional students (Souder, 1993), yet no significant difference in positive attitudes toward course material was apparent between distance and traditional education (Martin & Rainey, 1993). When comparing modes of instruction, conventional instruction was perceived to be better organized and more clearly presented than distance education (Egan, et al., 1991). From this, it was found that distance learners valued instructors who were well prepared and organized. Learners benefitted significantly from a well-designed syllabus and presentation outlines (Egan, et al., 1991). To expound on this, Egan and his colleagues suggested that structured note taking, the use of tools such as interactive study guides, and the use of visuals and graphics as part of

the syllabus and presentation outlines contributed to student understanding of the course. Learners received more from the course when the instructor seemed comfortable with the technology, maintained eye contact with the camera, repeated questions, and possessed a sense of humor (Egan, et al., 1991).

Further research by Threlkeld & Brzoska (1994) found that many distance learners required support and guidance to make the most of their distance learning experiences. This support was typically in the form of some combination of student-instructor and student-student interaction. Frequent interaction among the players of the distance learning theater was shown to result in increased motivation on the part of the learner (Coldeway, et al., 1980). It was suggested that more structured contact might be utilized as a motivational tool in distance education.

### **Chapter 3: The Current Model of Distance Education in Newfoundland and Labrador.**

The current model of delivery of distance education courses in the province of Newfoundland and Labrador relies on the printed page for course material and on an audio-graphic mode of communication for live contact. The communication aspect of the current model of delivery utilizes the **Telemedicine Centre's TETRA (Telemedicine and Educational Technology Resources Agency)** network. This is essentially an analog network that uses a combination of audio and computer text, as well as data and graphics commonly referred to as **audio-graphics** technology. There are currently only 12 senior high school courses offered by this mode in 82 small rural schools throughout the province (Boone, 1998).

This current mode of communication tends to be somewhat costly and is scheduled on the hour. These factors mean that contact with students can only occur at the scheduled times and instructional time is limited. As a result, the important aspect of frequent interaction with the learner is arduous. Another disadvantage of the **TETRA** network is that not all communities or schools have direct access to the **Telemedicine** equipment. Residents of some communities may have to commute to a distant community to avail of the **Telemedicine** services. The equipment is costly and requires technical support to maintain and ensure successful functioning. Therefore, the number of schools and communities that can avail of this type of delivery for distance education is limited. Another problem with the current model of delivery of distance education is

that it relies heavily on a print component. Modification or improvements in the print component of these current courses would be costly and could occur only on a yearly basis with the printing of new editions.

#### **Chapter 4: The Future of Distance Education.**

The problems outlined above are being addressed by the proliferation of the Internet. The Internet is the largest, most powerful computer network in the world. It is currently estimated that the Internet encompasses more than 1.3 million computers with Internet addresses that are used by up to 40 million people in more than fifty countries. "As more and more colleges, universities, schools, companies, and private citizens connect to the Internet either through affiliations with regional not-for-profit networks or by subscribing to information services provided by for-profit companies, more possibilities are opened for distance educators to overcome time and distance to reach students" (Kochmer, 1995, p.2).

As a result of initiatives by **Stemnet/SchoolNet**, all schools in Newfoundland and Labrador now have Internet access. Through federal initiatives such as **CAP** (Community Access Program), all remote communities of the province of Newfoundland and Labrador now have Internet access. As a consequence, a viable alternative now exists to provide people in rural communities of Newfoundland and Labrador an opportunity for educational experiences that otherwise would be impossible. Accessing instruction does not have to be tied to a rigid schedule, since the Internet can provide 24 hours of communication to any or all participants. The cost of this convenience is merely the cost of a long distance telephone call or a subscription fee to an Internet provider.

The power and convenience of the Internet has finally been recognized for more than mere "surfing" for facts and figures. It is now up to educators to utilize the Internet

to reach and teach students in geographically disadvantaged areas.

As indicated by Locatis and Weisberg (1997), the Internet provides a total package. The program is accessible immediately, there is only one edition to maintain, and that edition will always be the most current. Synchronous and asynchronous network communication allows time flexibility, and information can be delivered directly to your computer desktop. The Internet allows simultaneous two-way communication or multi-point communication among people at diverse sites.

With access to the Internet, distance educators and their students can use a variety of tools for communication:

- **Electronic mail (e-mail)** - Like postal mail, e-mail is used to exchange messages or other information with people. Instead of being delivered by the postal service to a postal address, e-mail is delivered by Internet software through a computer network to a computer address. This would allow students to contact their teachers or other students in the course in a consistent and cost effective manner.
- **Bulletin boards** - Many bulletin boards can be accessed through the Internet. A special bulletin board can be established for each specific course. The bulletin board would allow students or teachers to post questions and responses that all involved in the course could read. Relationships could be developed that would encourage students to respond to each other as well as to the teacher in an open forum. This

would be similar to the forum that would take place in a regular classroom.

- **World-Wide Web (WWW)** -The **WWW** is an exciting and innovative front-end to the Internet. Officially WWW is described as a "...wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents" (Hughes, 1994). The WWW provides Internet users with a uniform and convenient means of accessing the wide variety of resources (pictures, text, data, sound, video) available on the Internet.

With improvements in computer technology and developments in satellite technology, the Internet has become more and more convenient and easy to use.

## **Chapter 5: Considerations for Web Course Development of Distance Education Courses.**

The latter part of the twentieth century has seen a shift in the paradigm of meaningful learning. Proponents of the cognitive view of learning have boldly designated the learner as the focal point of the learning process. As indicated by Wittrock (1989), "learners became the sources of plans, intentions, goals, ideas, memories, strategies and emotions actively used to attend to, select, and construct meaning from stimuli and knowledge from experience"(p. 345). With this orientation, the learner's ideas and thoughts are considered to be important and very fundamental to the learning process. According to Wittrock, students must be "generative" in which they must actively participate in the learning process by linking new stimuli to prior knowledge and experience. It is the active mental participation by the learner which ultimately will guide learning and instruction.

Being aware of diverse learning backgrounds of students, the teacher's role is now to "design our tasks in such a way as to make students organize, structure, and relate ideas to prior knowledge"(Seifert, 1995, p.6). In a sense, the responsibility of learning shifts more towards the learner. In terms of pedagogy, this means that teachers must refrain from teaching exclusively facts and figures. Instead, the focus should be on strategies to teach learners how to learn. "Good teaching includes teaching students how to learn, how to remember, how to think, and how to motivate themselves"(Weinstein and Mayer, 1986, p. 315).

The primary role of the student is to learn. Under the best of circumstances, this challenging task requires motivation, planning, and the ability to analyze and apply the information being taught. In a distance education setting, the process of student learning is more complex for several reasons (Schuemer, 1993):

- In distance education, the learner is usually isolated. The motivational factors arising from the contact or competition with other students is absent. The student also lacks the immediate support of a teacher who is present and able to motivate and, if necessary, give attention to actual needs and difficulties that present themselves throughout the duration of the course.
- Distant students and their teachers often have little in common in terms of background and day-to-day experiences. Therefore, it takes longer for student-teacher rapport to develop. Without face to face contact, distant students may feel ill at ease with their teacher as an "individual" and uncomfortable with their learning situation.
- In distance education settings, technology is typically the conduit through which information and communication flow. Until the teachers and students become comfortable with the technical delivery system, communication will be problematic.

Beginning students may have some difficulty determining what the demands of a course of academic study actually are, because they do not have the support of an

immediate peer group, ready access to the instructor, or familiarity with the technology being used for delivery of the distance-education course. Students report that they value the presence of a learning group, and that the informal interactions that occur before and after and sometimes during a formal class are valuable components of the total learning experience. Basically, learning at a distance is not what most students prefer (Schlosser & Anderson, 1994). They may be unsure of themselves and their learning. Morgan (1991) suggests that distant students who are not confident about their learning tend to concentrate on memorizing facts and details in order to complete assignments and write exams. As Ault (1985) points out, "rote learning often defeats students with a burden of memorization without purpose, a strain from acquiring information without structure, and a frustrating emphasis on reproducing information exactly as presented"(p.39). As a result, the learner completes the course with a poor understanding of the material. Morgan (1991) views memorization of facts and details as a "surface approach" to learning and summarizes it as follows:

**Surface approach:**

- Focus on the "signs" (e.g., the text or instruction itself).
- Focus on discrete elements.
- Memorize information and procedures for tests.
- Unreflectively associate concepts and facts.
- Fail to distinguish principles from evidence, new information from old.
- Treat assignments as something imposed by the instructor.

- External emphasis focusing on the demands of assignments and exams leading to a knowledge that is cut-off from everyday reality.

Distant students need to become more selective and focused in their learning in order to master new information. The focus of their learning needs to shift them from a “surface approach” to a “deep approach”. Morgan (1991) summarizes this approach as follows:

**Deep Approach:**

- Focus on what is “signified” (e.g., the instructor’s arguments).
- Relate and distinguish new ideas and previous knowledge.
- Relate concepts to everyday experience.
- Relate and distinguish evidence and argument.
- Organize and structure content.
- Internal emphasis focusing on how instructional material relates to everyday reality.

Morgan (1991) cautions that teaching and learning at a distance is demanding. However, learning will be more meaningful and “deeper” for distant students if the students and their instructor share responsibility for developing learning goals and objectives, actively interact with class members, promote reflection on experience, relate new information to examples that make sense to learners, maintain self-esteem, and evaluate what is being learned. This is the challenge and the opportunity provided by distance education.

Although technology plays a key role in the delivery of distance education, educators must remain focused on instructional outcomes, not the technology of delivery.

The key to effective distance education is focusing on the needs of the learners, the requirements of the content, and the constraints faced by the teacher, before selecting a delivery system. An article that appeared in the final issue of **Prospects** by Kerr and Hajek (1998) sends a warning to Web course developers. They caution developers not to get caught up in the technology. "High resolution imagery and animation may look quite impressive but before you take the time and energy to integrate such features into a course, consider whether they truly are going to assist in conveying the intended message"(Kerr & Hajek, 1998, p. 20). Kerr and Hajek (1998) suggest that the foundation of the course is to have a predetermined structure which involves presentation, practice and guidance. As suggested by Creed and Plank (1998), "students will be only temporarily impressed by flash and dazzle. Long term impact depends on substance"(p. 9). The home page for the Web-based course should help students to find necessary course information, learn the material, and get involved in thinking about the course material (Ackermann, 1996). Properly designed home pages will encourage thought, discussion and active participation by distant students. Typically, this systematic approach will result in a mix of media, each serving a specific purpose. For example:

- A strong print component can provide much of the basic instructional content in the form of a course text, as well as readings, the syllabus, and day-to-day schedule. The print component of a Web-based course can be published on a Web page to be printed or viewed at the learner's convenience.

- Interactive audio or video conferencing can provide real-time, face-to-face (or voice-to-voice) interaction. This is also an excellent and cost-effective way to incorporate guest speakers and content experts.
- Computer conferencing or electronic mail can be used to send messages, assignment feedback, and other targeted communication to one or more class members. It can also be used to increase interaction among students.
- Pre-recorded digital video clips can be used to present demonstrations of laboratory techniques or demonstrations to enhance the learning of key concepts for visually oriented content.
- Fax machines can be used to distribute assignments, answer keys, last minute announcements, to receive student assignments, and to provide timely feedback for laboratory activities, assignments and tests.

Using this integrated approach, the educator's task is to carefully select among the technological options. The goal is to build a mix of instructional media, meeting the needs of the learner in a manner that is instructionally effective and economically prudent.

Instructional development provides a process and framework for systematically planning, developing, and adapting instruction based on identifiable learner needs and content requirements. This process is essential in distance education, where the instructor and students may share limited common background and typically have minimal face-to-face contact. Although instructional development models and processes are numerous

(Dick & Carey, 1990; Gustafson & Powell, 1991), the majority follow the same basic stages of Design, Development, Evaluation, and Revision as in figure 5.1 below.

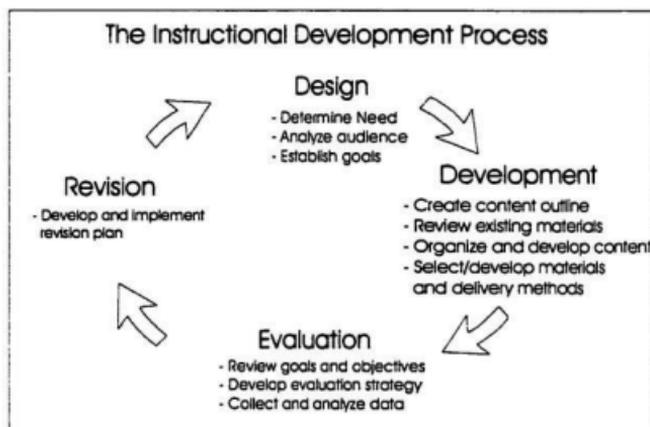


Figure 5.1: The Instructional Development Process .

**Chapter 6: Components of this Project.**

This project focused on the development of the following components:

- A. **A curriculum outline component.** In this component, intended learner outcomes had to be written and correlated with the general outcomes of the Advanced Placement Chemistry Curriculum set forth by the College Board.
- B. **A lesson component.** The lessons had to be correlated to the intended learner outcomes established in part A.
- C. **A laboratory component.** The laboratory component had to complement the lessons produced in part B. A laboratory component had to meet the pedagogical components of a sound science curriculum.
- D. **An evaluation component.** As with any form of distance education, evaluation poses a problem. The aspect of evaluation for this course required thought and ingenuity.
- E. **A navigation component.** The entire course had to be integrated and organized with a navigation scheme that was easy and convenient to use.
- F. **A communication component.** The communication component had to integrate the delivery of all of the above components using existing Internet delivery software. This component required the integration of text components, synchronous (live) communication, and asynchronous communication.

Although not a component of the course, a goal of this project was to foster computer literacy. Students were expected to gain valuable experience in the operation of the Internet. They were involved, on a day to day basis, with online live video-conferencing, accessing Internet materials via Internet links, bulletin boards, and e-mail. Students were also given the opportunity to share ideas with other students in these sessions via bulletin boards, e-mail, and audio/video conferences.

Finally, in the development of this project, the developer's computer literacy skills were enhanced and a better understanding of the challenging aspects of teaching and learning at a distance was achieved.

**Part A: The Curriculum Outline Component.**

As one of the first tasks, intended learner outcomes (ILO's) had to be written to match the general outcomes of the Advanced Placement Chemistry Curriculum set forth by the College Board. To view the College Board course content, consult appendix A or the Internet link at:

[www.collegeboard.org/ap/chemistry](http://www.collegeboard.org/ap/chemistry)

The ILO's can also be viewed in appendix B or at the following Internet link:

[http://www.stemnet.nf.ca/~vsddi/apchemistry/course\\_outline.htm](http://www.stemnet.nf.ca/~vsddi/apchemistry/course_outline.htm) .

The sample *course outline* page below, figure 6.1, can also be found hyperlinked within the index page.

In order to develop independent learning skills, the learner required an organized systematic approach to completion of the learner outcomes of the curriculum. Attention was therefore given to the ILO's of the course and also to the motivation and learning styles of the intended learners. The resource materials: textbook, study guide, CD-ROM, laboratory activities, and problem sets were correlated to the ILO's. Each topic of the AP Chemistry College Board content was broken down into a unit of study that would comprise roughly one hour of time allotted for one lesson. Figure 6.1 below shows a topic with the associated ILO's, the appropriate textbook references, as well as an associated laboratory activity.

Section 2: Atomic Mass

Learning Objective	Text Sections	Text Pages
1. To describe the modern atomic mass scale and explain how atomic masses are determined experimentally (Section 3.1.3.3)	3.1-3.5	80-99
2. To demonstrate the calculation of the mass percent a given element in a compound (Section 3.4)	Study Guide Sections	Study Guide Pages
3. To demonstrate the calculation of the empirical and molecular formula of a compound (Section 3.5)	3.1-3.5	42-53
4. To show how to obtain the molecular formula, given the empirical formula and the molar mass (Section 3.5)		

Lab 1 Empirical Formula of Magnesium Oxide

Figure 6.1 Sample Course Outline Page.

**Part B: The Lesson Component.**

Development of the lesson component was ultimately the most significant task of this project. The lessons had to be well organized and matched to the ILO's. Many of the concepts encountered in the study of chemistry generally tend to be somewhat remote and abstract. Therefore, the lessons had to utilize computer animated models and simulations to ease the understanding of abstract science concepts. For instance, Bean, Searles, Singer & Cowen (1990) state that "research in learning from text in science suggests that reasoning by analogy is one way that students may develop knowledge structures for unfamiliar concepts"(p. 233). In keeping with this, the lessons were supplemented by the inclusion of links to related Internet resources such as: online simulations, links to similar AP Chemistry sites, or other sites that were pertinent to the curriculum.

The final product of this project is composed of 72, 1 hour lessons. Representative samples of these lessons can be viewed in appendix C or via the Internet as mentioned in the navigation discussion. A sample lesson can be viewed at:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/units/unit1/topic1/section5/lesson1/sec05les01.htm>

The following, figure 6.2, is a sample of the headers of a lesson page.

Section 5 Lesson 1 - Microsoft Internet Explorer

*Curriculum Outcomes*

1. To characterize oxidation-reduction reactions.

● Lab 10

*Section 5*

*Lesson 1: Oxidation - Reduction Reactions*

REFERENCE  
**Chemistry** 4th Edition  
 Zumdahl  
 © 1997  
 Houghton Mifflin Company

• Text Section 4.9, pp 164 - 165  
 • Study Guide Section 4.9, pp 28 - 31

Figure 6.2: Sample Lesson Page (Header)

For reasons of consistency, all lessons followed the same visual layout. Each lesson consisted of two frames. Located within the top frame, were the ILO's for the associated lesson. The ILO's were included with each lesson as a means of providing sound pedagogy. For each lesson the learner was aware of what was expected to be learned. The curriculum outcomes frame could also be printed, so that the learner would have a printed copy of the ILO's.

The lesson frame was made larger and was positioned below the curriculum outcomes frame. The lesson frame contained the relevant textbook and study guide references. Without scrolling down the screen or further navigation, the learner would be able to see the ILO's and the relevant background textbook references. This provided the learner with a sense of knowing exactly what was expected and where to open one's

textbook to find the relevant material. The top and bottom of each lesson included navigation buttons that could be used to go to the top or bottom of the lesson, or to move to a previous or next lesson. This navigation feature provided the learner with quick and easy movement throughout the lessons.

The instructional material provided in the lessons were not intended to be used as an exclusive resource. The objective of the project was not to recreate a textbook online. The textbook selected for the AP Chemistry course was: *Chemistry* 4th Edition by Zumdahl (1997). This particular textbook was very current and very well written, attending closely to pedagogy issues as well as focusing on chemistry content. For this reason, the lessons for this project had as its main goal, supplementation of the textbook material. Therefore, many of the lessons provided the learner with an alternative mode of instruction or instructional perspective. Throughout the lessons, where appropriate, the use of animation, videos, still pictures, related Internet links, analogies, examples, demonstrations, personal experience, as well as other learning tools and strategies were employed to convey the course material. For example, an animated gif was used which created an analogy to aid in the explanation of diffusion rates for gases. To view this animation, see the lesson in Unit 1, Topic 2, Section 2, Lesson 1 or at the following link:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/units/unit2/topic1/section2/lesson2/sec02les02.htm>

A few of the lessons were merely a review of material covered in the prerequisite high school curriculum of Chemistry 2202 and Chemistry 3202. For instance, the lesson on the gas laws:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/units/unit2/topic1/section1/lesson1/sec01les01.htm>

These review lessons simply provided the learner with a reference to the textbook, a quick review of the ideas and a list of practice problems. The rationale was to review material that should have been already addressed in the authorized high school curriculum.

At the bottom of each lesson, the learner was provided with a series of related questions from the textbook. This was meant to provide the necessary practice required to further assimilate the material covered. For the more difficult questions, the question number was hyperlinked to hint pages that provided the learner with hints on how to proceed to answer the particular question.

The lessons were also hyperlinked to the related laboratory activities. This was necessary so that the learner could quickly relate the material to be learned with hands on practical science. Throughout each lesson, attention was drawn to sample exercises in the textbook and study guide, as well as reference to the interactive CD-ROM that accompanied the textbook.

**Part C: The Laboratory Component.**

Fundamental to the learning of scientific concepts and skills, is a laboratory component. As eloquently put by Erasmus Darwin (1731-1802), "A fool ... is a man who never tried an experiment in his life"(Ross and Scanlon, 1995, p.133). Well planned laboratory activities provide a link to the abstract concepts often encountered in the field of chemistry. Laboratory activities provide the opportunity to develop psychomotor skills, observation and measurement skills, and skills of handling data. As indicated by Ross and Scanlon (1995), laboratory activities give the learner "a feel for the phenomena, thus allowing them to build up personal and practical experience in their subject, and to develop some appreciation for the real world"(p. 134). From personal experience, laboratory activities serve to motivate and captivate the interest of the learner. Therefore, a set of laboratory activities that coincided with the AP Chemistry curriculum, which were pedagogically sound, safe, and cost effective, were developed.

As predicted, the development of the laboratory component of the course presented somewhat of a challenge. The laboratory activities were intended to be performed at a distance, making the issue of safety paramount. As indicated by Worthy (1988), "the single most challenging aspect of teaching chemistry at a distance is devising a means of providing the laboratory component of the course"(p. 15). Performing experimental work in chemistry requires knowledge of chemical reactions, safety procedures, and, ultimately, experience with working in a laboratory setting. Therefore, on-site supervision of the student was considered essential in the development

of the laboratory component of this project.

The laboratory activities selected had to be relevant to the course material and developed to meet the needs of the learner. A successful AP candidate requires the laboratory skills and experiences equivalent to a first-year college chemistry course. The result was a set of 12 comprehensive laboratory activities. A printed copy of representative laboratory activities may be viewed in appendix D. To view the complete set of laboratory activities online, consult the Web-CT lessons page or the following Internet link:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/index.htm>

All laboratory activities were carefully developed to move step-by-step through procedures. No aspect of the laboratory activity was left to guess work. Safety concerns were addressed with appropriate descriptions of what to do in case of spills or accidents. The choice of laboratory activities and chemicals used were selected to minimize potentially dangerous situations.

To provide the student with demonstrations of safe laboratory techniques, online video was used. These videos demonstrated many techniques previously unused or unseen by most students enrolled in the course. Laboratory and demonstration videos were filmed on site in the chemistry laboratory at Discovery Collegiate, Bonavista. Many hours of setting up, shooting videos, performing takes and retakes, editing the shots, adding audio, and finally compressing the videos was indeed a learning experience. With the help of a few interested students, the filming task was shortened considerably, but the

overall process still required several weeks.

The video was filmed using a high quality 8mm video camera. During the recording phase, the camera was hooked up to a television set so that each phase of the recording process could be monitored. The videos were then digitized and edited using a software package called Adobe Premiere. Once the desired video was edited for time and content, audio was added. The audio portions were simply voice recordings using the sound recording accessory in Windows 95 . The video and audio portions were then combined and synchronized using Adobe Premiere.

The audio/video product produced in Adobe Premiere tended to result in files that were quite large. This presented a problem. The time required to transmit such large video files over the Internet was substantial, depending on location and the hardware being used by the learner. To overcome this, the videos were compressed using a software package called RealPlayer G2. This utility compressed the regular digital video to a fraction of its original size. In doing so, some of the resolution quality of the original video was lost during the compression process. The audio quality was not adversely affected by compression. The result was good quality video that was capable of quick transmission, reducing transmission time by as much as 90%. In any case, to alleviate any loss of resolution or transmission time problems, the original non-compressed videos were copied onto a CD-ROM and distributed to all learners involved in the course.

The laboratory procedures included still shots of apparatus and color images of important items or procedures. The use of color bitmap images provided the

experimenter with the actual equipment used. The color images also provided the student with the possible array of colors that could be observed when they used such things as indicators. For instance, the indicator phenolphthalein changes from colorless to pink at the equivalence point in an acid-base titration procedure. The array of pink hues that could be possible when performing a titration was no longer a problem. The experimenter had online images comparing the desired shade of the indicator with the range of pink shades that may have been observed. To view this laboratory activity see the following Internet link:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/labs/lab06/lab06.htm>

Still shots used throughout the laboratory activities were merely captured frames of video. Adobe Premiere also allowed the user to capture individual frames from videos. This feature limited the cost of needing a digital camera for still shots. Thus, the high quality 8mm video camera had served a dual role.

The laboratory activities also included hyperlinked data tables for the recording of results. These standard tables were intended to be used by the student to record their experimental results. The tables included headings for name and school which were to be faxed along with the laboratory report. The following figure 6.3 is a sample data table.

Table 6.1: Titration of Sodium Hydroxide with 25.00 mL of Standard 0.10 mol/L Hydrochloric Acid

Name: \_\_\_\_\_ School: \_\_\_\_\_

**Table 6.1: Titration of Sodium Hydroxide with 25.00 mL of Standard 0.10 mol/L Hydrochloric Acid**

Indicator: Phenolphthalein colorless in acid - pink in base.

Burette reading (mL)	Trial #1	Trial #2	Trial #3
Final			
Initial			
Volume of NaOH used			
Average of two closest trials:			

Figure 6.3: Laboratory Data Table.

The laboratory activities also included a step-by-step analysis section. The intent was to limit any confusion or questions that would inevitably emerge during the write-up of the laboratory report.

**Part D: The Evaluation Component.**

Effective teachers use a variety of means, some formal and others informal, to determine how much and how well their students are learning. For example, to formally evaluate student learning, most teachers use evaluation tools such as: quizzes, tests, examinations, term papers, laboratory reports, and homework. These formal evaluation techniques help the instructor evaluate student achievement and assign grades.

Formative and summative evaluation components of unit testing, assignments, laboratory activities, and an online research activity were developed for the course during this project. There were 7 assignments developed for this course. These assignments were a list of questions pertaining to each section of study. These assignments could be accessed via the Web-CT calendar or through the index page. To view a printed copy of an assignment, consult appendix E or view the assignments online at the Internet link:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/index.htm>

Student assignment reports were to be faxed back to the instructor for quick response and feedback. Timely response of student work was considered essential in the learning process. Quick feedback provided the students with an indication of their level of success and understanding. In response to this, students were able to access the solutions to the assignments online immediately after the submission date of the assignment. By simply activating the hyperlink to the solution page, students everywhere had immediate access. To view a sample solution page, consult the assignment site above or see appendix E.

A set of 6 unit tests were also developed for the course. These tests were delivered via e-mail to the co-operating teacher in each school. The tests were written by the students on prescribed dates and then faxed back to the instructor for correction. The tests were designed with a standard layout and included standard response sheets. Standardization was used to provide the student with a comfortable level of familiarization with the evaluation tool. A representative sample of the unit tests can be viewed in appendix F.

### Part E: The Navigation Component.

As mentioned previously, a well organized easily accessible navigation scheme throughout the course was essential. Careful attention was paid to navigation so that it would be developed in such a way as not to hinder the learning process. Considering this, three modes of navigation were established.

The first mode of navigation was via the **Web-CT calendar**. To view this, simply click on the **Calendar** icon within the Web-CT main page. A sample of this page can be seen in figure 6.4 below.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	<u>1</u> - Lesson #47	<u>2</u> - Lesson #48	<u>3</u> - Lesson #49	<u>4</u>	<u>5</u> - Lesson #50	<u>6</u>
<u>7</u>	<u>8</u> - Lab #8	<u>9</u>	<u>10</u> - Lesson #51	<u>11</u> - Lesson #52	<u>12</u>	<u>13</u>
<u>14</u>	<u>15</u> - Holiday!!!!!! Ya HOOI	<u>16</u> - Lab #8 due	<u>17</u> - Lesson #53	<u>18</u> - Lesson #54	<u>19</u>	<u>20</u>

Figure 6.4: Calendar Navigation Page.

In this mode of navigation, the learner followed the course as it was laid out day-to-day, by the instructor. Students simply logged on to Web-CT through the Internet and

access the calendar, then pointed and clicked on the day's lesson.

The calendar mode of navigation was very useful for a number of reasons. It offered the students a plan of attack by setting the pace of instruction. At a glance, students could quickly see what was expected from day-to-day or week-to-week, in terms of the lessons that they should have been working on. The calendar was also used to show important dates such as when laboratory activities were to be done, assignment due dates, as well as test days. By having the course laid out day-to-day, a time-line was established which provided the necessary structure that was so important for the independent learner. From an instructional view, the calendar was easily maintained and provided quick and easy delivery of the course curriculum.

The second mode of navigation developed was that of a **hierarchy approach**. This scheme can be viewed by clicking on the *lesson* icon in the Web-CT main screen or at the following link:

<http://www.stemnet.nf.ca/~vsddi/apchemistry/index.htm>

In this mode, lessons were organized by the course objectives by means of a tree-like navigation scheme. Navigation was handled by the use of expanding and collapsing hierarchies in which the learner clicked on the desired topic and the list of related course outcomes were expanded. The lessons within the hierarchy were then hyperlinked to the lesson Web page material. Figure 6.5 below is a sample of a partially expanded outline.

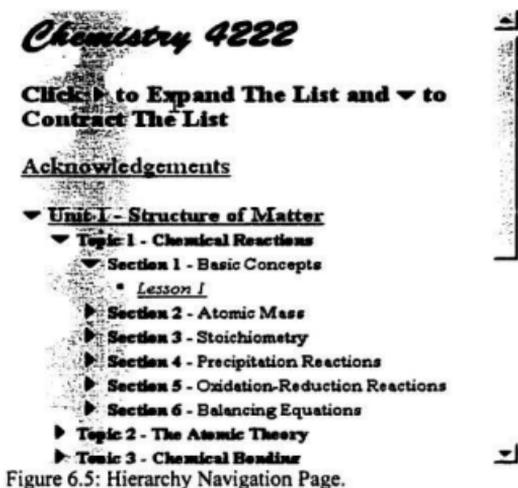


Figure 6.5: Hierarchy Navigation Page.

Although this mode of navigation had no time-line association, it still had value.

The hierarchy provided a visual structure to the course. It showed the student the connection of the lessons within the topics and ultimately within the total course. This hierarchy could be printed at any stage. Complete expansion of the hierarchy provided the learner with an organizational checklist of lessons correlated with the course ILO's. For the independent learner, this proved to be an essential organizational tool.

The third navigation scheme can be viewed by clicking on *course outline* within the hierarchy main page mentioned above or at the following link:

[http://www.stemnet.nf.ca/~vsddi/apchemistry/course\\_outline.htm](http://www.stemnet.nf.ca/~vsddi/apchemistry/course_outline.htm)

The course outline page consisted of a table of ILO's. Within the table, hyperlinks to associated lessons and laboratory activities were accompanied by the

prescribed textbook and study guide reference pages. Once again the table served as a check list giving the student a sense of direction and organization, but this time with quick reference to the textbook and study guide material. Figure 6.6 below is an example of a section of the total outline page.

Section 2: Atomic Mass

LI		Text Sections:	Text Pages:
1.	To describe the modern atomic mass scale and explain how atomic masses are determined experimentally (Section 3.1.3.3).	3.1-3.5	80-99
2.	To demonstrate the calculation of the mass percent a given element in a compound (Section 3.4).	Study Guide Sections:	Study Guide Pages:
3.	To demonstrate the calculation of the empirical and molecular formula of a compound (Section 3.5).	3.1-3.5	42-53
4.	To show how to obtain the molecular formula, given the empirical formula and the molar mass (Section 3.5).		

Lab 1 Empirical Formula of Magnesium Oxide

Figure 6.6 Sample Course Outline Page (Navigation).

**Part F: The Communication Component:**

As mentioned previously, Web-CT is a comprehensive Web tool specifically designed for the delivery of Web-based courses. For this project, Web-CT provided a secure and easy method for the delivery of lessons, assignments, quizzes, personal student information, as well as an integrated communication component. Since the Web-CT package was provided by Stemnet, it was the delivery package of choice. As mentioned previously, Stemnet is available in every school in the province of Newfoundland and Labrador. Therefore, every student in the province has the ability to access this Web-based course.

Web-CT, an icon driven application, was easy to use by the learner and equally easy to administer by the facilitator. To view the course through Web-CT, login as *username:Student* with a *password:education* to the following Internet site:

[www.stemnet.nf.ca/~vsddi](http://www.stemnet.nf.ca/~vsddi)

A sample of the main page from Web-CT can be viewed in figure 6.7 below. To use the page, simply point and click on the icons. From this page, students were able to access lessons, laboratory activities, and assignments quickly and easily through the calender or lessons icon. They could also activate the bulletin board or private e-mail from this page or even check out their latest marks.

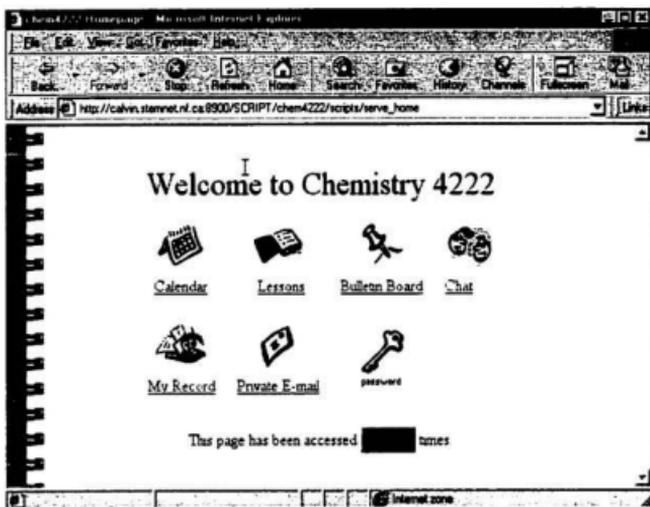


Figure 6.7: Web-CT Main Page.

This Web-based course was also designed to incorporate a component of online instruction. This involved two distinct forms of communication: synchronous communication and asynchronous communication. The asynchronous aspect of the course was handled by e-mail using Sternnet and Web-CT. Web-CT utilized e-mail, as well as an electronic bulletin board local to the students registered in the course. The bulletin board allowed messages to be posted to the whole group such that everyone within the group could see the questions and responses, similar to a group forum. This was a useful way of posting questions to the entire class in an effort to generate group

discussion. The group discussion aspect served to provide the essential peer-to-peer interaction that was generally missing in distance education courses. The bulletin board provided a way of answering questions for the whole group. For example, a student may have had a question answered by consulting the bulletin board of previously addressed questions. For the students that had more personal matters or those that were reluctant to address the group, teacher-student interaction had taken place through regular private e-mail. For sample e-mail exchanges that took place throughout the course, view appendix G.

Of course, the traditional modes of communication: phone, fax, and regular mail were also available. In fact, the distribution and collection of tests were primarily handled by fax and regular mail. Midway through the year, when co-operating teachers became more comfortable with e-mail, tests were sent as e-mail attachments. Assignments were delivered via the Internet as Web pages, as mentioned previously.

Synchronous communication was handled via **Net-meeting** and **Meeting Point**. This combination of applications allowed real-time audio/video communication to several sites at the same time. Accompanied by the audio/video component, an electronic writing tablet was also employed. All students involved in the course had this piece of hardware which served the role of the traditional chalk board. This hardware device was used in a dual role. That is, both the instructor and the student had the opportunity in real-time, to write notes, pose questions, draw figures, graphs, and the like. For instance, the instructor could put forth a question and a student at a distance could answer the question

both verbally and pictorially using Net-Meeting. The following figure 6.8 was one of the many whiteboard screens saved during an actual lesson.

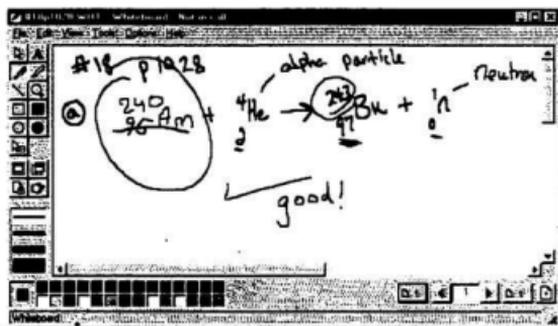


Figure 6.8: Whiteboard Screen of an Actual Lesson.

Net-meeting also allowed the sharing of applications among users at remote sites. This was an extremely useful teaching tool. A little background into how this worked may be necessary. A user at one site could start a program and share it with others at remote sites who were engaged in the meeting. The program executes from one site and could be seen and used by others at the remote sites, in real-time. An example of this use was the sharing of the spreadsheet application **Quattro Pro**.

Laboratory Activity #8, Chemical Kinetics: The Rate Laws, required several graphs to be generated from collected data. The students in Port Rexton had performed the experiment and collected their data. It was suggested that they consider doing their graphs with an electronic spreadsheet such as Quattro Pro. This idea was met with resistance because the students were not at all familiar with such applications. To ease

their concerns about Quattro Pro, a tutorial session from Bonavista was conducted with students logged on at the same time from Clarendville and Port Rexton. At the end of the tutorial, the students were creating their own graphs while their progress was simultaneously monitored by the instructor. This was truly interactive teaching and learning at a distance.

**Chapter 8: Reflective Analysis.**

Upon reflection on the development and delivery of this Web-based pilot course, many concerns and challenges emerged. In order to move forward and improve Web-based distance education course development and delivery, a critical analysis of this project is essential. The analysis that follows details the challenges of developing and delivery of this Web-based pilot course for the 1998-99 school year.

**Challenges of Developing a Web-based Course.**

As indicated in the acknowledgments, the development of this Web-base course for the Vista District Digital Intranet involved many parties giving a substantial amount of time and effort. The amount of effort represented in the development of this course required several months of full time involvement. Such tasks as the editing of digital video, which was already an arduous task, was not possible on a simple home computer. The use of one of Stemnet's state of the art computers, on site at Memorial University, made the tasks much more achievable.

One of the initial challenges faced was the reality that the process of developing a Web-based course was new and unfamiliar for many involved. As a result, a great deal of time was spent trying to learn new software or techniques in an effort to get an understanding of what was capable with the tools available. A great deal of time was also spent examining other similar courses already developed for use on the Internet.

Another challenge that at first seemed simple, but later realized to be much more complex, was the aspect of standard file conventions. It was crucial to develop a mode of consistent file naming. In the development of an entire Web-based course, a massive number of files were generated. In order to aid in organization for quick and easy retrieval of these files, it was important that standards be developed before any substantial work was done.

An added challenge was imposed by the Centre for TeleLearning and Rural Education. The Centre stipulated that all four courses being developed in the overall project: AP Biology 4221, AP Chemistry 4222, AP Physics 4224 and AP Math 4225 had to have a consistent structure. These courses were developed by four different individuals under somewhat variable conditions. At times, it was difficult to work under such constraints. However, in the end the commonality of the four courses was a positive feature of the total package.

Probably the most important lesson learned in the development of this curriculum project was to establish thorough planning. Working with firm deadlines meant that the project had to be well organized and planned. All of the components of the course had to be developed and ready for use in the coming school year.

**Challenges of Delivery of this course via the Internet in the 1998-99 school year.**

The delivery of this Web-based version of AP Chemistry in the 1998-99 school year presented several challenges. Early in the school year it was apparent that some students enrolled in the AP Chemistry course did not have a realistic view as to what was required. With such a substantial workload presented in the AP Chemistry course, it was found that most students quickly fell behind the pace of instruction. A pace was set in order for students to be prepared to write the College Board AP Chemistry exam, usually scheduled in mid-May. Such an early date, in itself, challenged students by shortening the length of a typical school year, thus reducing instructional time.

Most of the students enrolled in the course were familiar and comfortable with a face-to-face learning environment. However, under the conditions in which they were given considerable independence, many students were unable to make adequate adjustments. In general, most students tended to waste their class time, and did not adequately prepare themselves prior to laboratory work or online sessions.

Early in the school year, tremendous technological setbacks had occurred. The utilization of the intended live, online instruction was slow to commence. It was near the middle of the school year before the online sessions became of any significant value. As a result of this breakdown with the Internet communication component, many students were perceived as seeing the breakdown as a reason for lack of effort in the course. However, all other aspects of the course were intact and functioning as intended. The lack of effort on the part of the students may have been due to their lack of familiarity

with the technology or their mental unpreparedness to tackle such a challenging and demanding course via a distance.

Scheduling problems among the various sites involved in this course also presented a challenge. Early in the development of this course, it was accepted that all schools in the district were to be operating on a common schedule. A fourteen day schedule had been generate by the district office and distributed to the schools. On the first day of school it was apparent that this was not the case. Throughout the district in the 1998-99 school year, five different schedules were in use. These schedules ranged from eight day, to fourteen day, to four by four, with varied instructional time periods. For the online sessions, the original master schedule was of little use. Online sessions occurred whenever student and teacher found common time. For some students, this meant missing instructional time from other courses or having sessions during recess and lunch breaks.

The laboratory component of this course was not a successful or positive experience for most students. Upon development of the AP Chemistry laboratory component, the assumption was made that a basic level of laboratory skills and laboratory techniques were developed by the student from the prerequisite Chemistry 2202 and Chemistry 3202 courses. However, throughout the year, it was found that this was not the case. Most students were only remotely familiar, if at all, with the simplest laboratory skills. In anticipation of this, laboratory activities for this course were provided with written instructions, including background information, list of materials, procedure and

videos demonstrations of techniques. Students were expected to prepare for the laboratory activities in advance and conduct the laboratory activities with on-site supervision. Even though students were provided with written laboratory instructions well in advance, few students had taken the initiative to prepare for the laboratory activities.

During the development of the laboratory activities, it was expected that on-site teachers would prepare for the delivery of the laboratory activities. These on-site teachers were then intended to supervise the students during the laboratory activity. Unfortunately, these teachers already had a full workload. Despite being scheduled in their own classes, many of these teachers were still willing to assist in any way. Unfortunately, many of these teachers were unfamiliar with the subject material and laboratory techniques. Therefore, many supervising teachers were unable to provide any real, meaningful assistance.

Finally, despite encouragement to use the resources provided, students tended to rely on the Web page information as their primary resource. Students were not accessing the video or animated portions of the course, nor were they utilizing the Internet links provided within the lessons. No substantial reason for this behavior was put forth by the students involved in the course. The information of the Web pages were merely point and click, which took no more time to load than it did to wait for their favorite Web site to load. Students in which this behavior was the norm quickly found themselves at a disadvantage. These students had missed the valuable interactive experience that was

originally designed into the resources. Behavior such as this severely inhibited the potential of the vast array of learning tools offered by this Web-based course.

From the challenges faced throughout the delivery of this course in the 1998-99 school year the following recommendations are made:

First of all, a student profile should be developed which would indicate the characteristics of a "Successful AP Student". Potential AP students need to be given a realistic idea of what doing an AP course means in terms of work load, requirement for computer skills, and the self-discipline required to work independently.

Another recommendation comes from the idea that optimal success could only be achieved if students were comfortable with using the technology. It was not sufficient to simply provide a student with a workstation and expect the student to know how to use it efficiently. Therefore, it is essential that formal training be provided to AP distance education students prior to starting a Web-based distance course. The training should include all applications utilized in the delivery of the course materials and online sessions. The following components should be considered: using Web-CT (My Records, Chat Rooms, Lessons, Quizzes, Bulletin Board, Private Mail, using attach to transfer assignments, etc.), Netmeeting and Meetingpoint (connecting to the Meetingpoint server, logging in, whiteboard, chat, efficient use of the microphone and speaker, etc), and using technological means to gather data during experiments.

With a large amount of time spent online, it is recommended that students be encouraged to have their own computer for home access, since "homework" now takes on

a new meaning. Accessing the course material no longer has to be limited to regular school hours. With a suitable computer at home and the skills to effectively use it, students may take advantage of the time flexibility that is offered by Internet delivery. Students do not have to wait to download information from the Internet during peak day time hours. By freeing up their class time, students are able to focus on the course material and prepare for online sessions and laboratory activities.

In terms of scheduling online sessions, it is necessary that all participating schools be on a common schedule. It is recommended that district personnel impose a common schedule that would accommodate the needs of the synchronous components of a distance education course.

The challenges presented by the delivery of the laboratory component can be addressed by attending to two specific recommendations. First, a district wide effort must be initiated to ensure that students and teachers involved in a distance AP Chemistry course have at least the basic levels of prerequisite Chemistry 2202 and Chemistry 3202 laboratory skills. In the case of this course, it would be essential that an on-site supervisor be in-serviced on the techniques involved in the various laboratory activities. Secondly, to facilitate the smooth delivery of the laboratory component of this course, co-operating teachers must be given time, in their schedule, to properly administer the laboratory activities in their schools.

In the case of the improper use of the learning resources, every effort must be made to ensure that students use the materials as intended. This may be addressed by an

information session, included as part of the technological training session mentioned above. The intended use of the learning resources could also be reinforced throughout the duration of the course. During online sessions, the learning resources could be integrated into the live student-teacher interactions. Students need to be made aware of the importance of these interactive learning resources to the effective learning of abstract concepts.

A strong commitment on the part of the many players involved in the delivery of this course is needed to act on these recommendations. Implementation of these recommendations would surely improve the delivery of this Web-based AP Chemistry course.

### **Conclusion.**

Overall, involvement in this project was an enormous learning experience. Throughout the project development, the developer gained a considerable understanding of the nature of learning and the nature of the learner. This project has also provided the opportunity to develop new computer skills that could be applied to an educational environment.

From experienced gained in the development of this course, it is evident that the Internet has much to offer the geographically disadvantaged learner of the province of Newfoundland and Labrador. Much more time and effort should be devoted to improve and further enhance such a potentially powerful educational tool. The Internet has essentially given a new focus to the future of distance education in the province of Newfoundland and Labrador.

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**Appendix A: AP Chemistry Course Content.**

### **AP Chemistry 4222 Course Content.**

Many of the general topics and sub topics listed below are the same as the topics currently present in the course descriptions for the Atlantic Provinces Chemistry Curriculum. However, the breath and depth of treatment of these topics are beyond the high school level and is comparable to that of first-year, post-secondary education. In some cases, the treatment is beyond first-year.

The following course content is based on the **College Board** guidelines. To view the College Board Advanced Placement Chemistry course content, consult the following Internet link:

<http://www.collegeboard.org/ap/chemistry/html/cours002.html>

#### **I. Structure of Matter.**

##### **A. Atomic theory and atomic structure.**

1. Evidence for the atomic theory.
2. Atomic masses; determination by chemical and physical means.
3. Atomic number and mass number; isotope.
4. Electron energy levels: atomic spectra, quantum numbers, atomic orbitals.
5. Periodic relationships including, for example, atomic radii, ionization energies, electron affinities, oxidation states.

**B. Chemical bonding .**

1. Binding forces.
  2. Polarity of bonds, electronegativities.
    - a. Types: ionic, covalent, metallic, hydrogen bonding, van der Waals (including London dispersion forces).
    - b. Relationships to states, structure, and properties of matter.
  3. Molecular models.
    - a. Lewis structures.
    - b. Valence bond: hybridization of orbitals, resonance, sigma and pi bonds.
  4. VSEPR theory.
  3. Geometry of molecules and ions, structural isomerism of simple organic molecules and coordination complexes; dipole moments of molecules; relation of properties to structure.
- C. Nuclear chemistry: nuclear equations, half-lives, and radioactivity; chemical applications.

**II. States of Matter.****A. Gases.**

1. Laws of ideal gases.
  - a. Equation of state for an ideal gas.
  - b. Partial pressures.

2. Kinetic-molecular theory.
  - a. Dependence of kinetic energy of molecules on temperature.
  - b. Interpretation of ideal gas laws on the basis of this theory.
  - c. Deviations from ideal gas laws.

**B. Liquids and solids.**

1. Liquids and solids from the kinetic-molecular viewpoint.
2. Phase diagrams of one-component systems.
3. Changes of state, including critical points and triple points.
4. Structure of solids; lattice energies.

**C. Solutions .**

1. Types of solutions and factors affecting solubility.
2. Methods of expressing concentration (The use of normalities is not tested).
3. Raoult's law and colligative properties (nonvolatile solutes); osmosis.
4. Non-ideal behavior (qualitative aspects).

**III. Reactions.**

**A. Reaction types.**

1. Acid-base reactions; concepts of Arrhenius, Brønsted-Lowry, and Lewis; coordination complexes; amphoterism.
2. Precipitation reactions.

3. Oxidation-reduction reactions.
  - a. Oxidation number.
  - b. The role of the electron in oxidation-reduction.
  - c. Electrochemistry: electrolytic and galvanic cells; Faraday's laws; standard half-cell potentials; Nernst equation; prediction of the direction redox reactions.

**B. Stoichiometry.**

1. Ionic and molecular species present in chemical systems: net ionic equations.
2. Balancing of equations including those for redox reactions.
3. Mass and volume relations with emphasis on the mole concept, including empirical formulas and limiting reactants.

**C. Equilibrium.**

1. Concept of dynamic equilibrium, physical and chemical; Le Chatelier's principle; equilibrium constants.
1. Quantitative treatment.
  - a. Equilibrium constants for gaseous reactions:  $K_p$ ,  $K_c$ .
  - b. Equilibrium constants for reactions in solution.
    - i) Constants for acids and bases;  $pK$ ;  $pH$ .

- ii) Solubility product constants and their application to precipitation and the dissolution of slightly soluble compounds.
- iii) Common ion effect; buffers; hydrolysis of a salt.

#### D. Kinetics.

1. Concept of rate of reaction.
2. Use of differential rate laws to determine order of reaction and rate constant from experimental data.
3. Effect of temperature change on rates.
4. Energy of activation; the role of catalysts.
5. The relationship between the rate-determining step and a mechanism.

#### E. Thermodynamics.

1. State functions.
2. First law: change in enthalpy; heat of formation; heat of reaction; Hess's law; heats of vaporization and fusion; calorimetry.
3. Second law: entropy; free energy of formation; free energy of reaction; dependence of change in free energy on enthalpy and entropy changes.
4. Relationship of change in free energy to equilibrium constants and electrode potentials.

#### **IV. Descriptive Chemistry.**

Knowledge of specific facts of chemistry is essential for an understanding of principles and concepts. These descriptive facts, including the chemistry involved in environmental and societal issues, should not be isolated from the principles being studied but should be taught throughout the course to illustrate and illuminate the principles. The following areas should be covered:

1. Chemical reactivity and products of chemical reactions.
2. Relationships in the periodic table: horizontal, vertical, and diagonal with examples from alkali metals, alkaline earth metals, halogens, and the first series of transition elements.
3. Introduction to organic chemistry: hydrocarbons and functional groups (structure, nomenclature, chemical properties). Physical and chemical properties of simple organic compounds should also be included as exemplary material for the study of other areas such as bonding, equilibria involving weak acids, kinetics, colligative properties, and stoichiometric determinations of empirical and molecular formulas.

#### **V. Laboratory.**

Although the current College Board AP syllabus does not list specific labs, suggested laboratory topics include:

- 1) Determination of the empirical formula of a compound.
- 2) Titration as a quantitative technique - acid-base titration.

- 3) Determination of the molecular formula of an unknown compound.
- 4) Stoichiometric relationships in chemical reactions.
- 5) Qualitative analysis for common substances.
- 6) Determination of the water of hydration.
- 7) Determination of molecular mass by freezing point depression.
- 8) Determination of the ideal gas constant  $R$ .
- 9) Determination of rate of reaction and reaction order.
- 10) Determination of  $K_{sp}$  of sparingly soluble salts.
- 11) Oxidation-reduction titrations.
- 12) Electrochemical cells and the electrochemical series.

**Appendix B: Intended Learning Outcomes.**

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# Chemistry 4222

## Intended Learning Outcomes

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Unit I: Structure of Matter

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**Topic A: Chemical Reactions**

**Section 1: Basic Concepts**

<u>L1</u>		<b>Text Sections:</b>	<b>Text Pages:</b>
	1. To determine the number of significant figures in single value and calculations ( <b>Section 1.5</b> ). 2. To name compounds and write formulas for: - Binary salts - Salts with poly-atomic ions - Binary covalent compounds - Acids <b>(section 2.8)</b> 3. To perform calculations involving; molar mass, mass from moles, moles from mass, number atoms from moles, moles from number of atoms ( <b>section 3.2 -3.3</b> ). 4. To write and balance chemical equations ( <b>section 3.7</b> ). 5. To perform calculations involving concentration, dilution, dissociation and ion concentration ( <b>section 4.3</b> ).	<b>1.5, 2.8, 3.2,3.3, 3.7,&amp; 4.3</b>  <b>Study Guide Sections:</b>  <b>1.5, 2.8, 3.2, 3.3, 3.7, &amp; 4.3</b>	<b>13-17, 59-70, 83-90, 102-107, 141-148</b>  <b>Study Guide Pages:</b>  <b>5-7, 27-34, 45-49, 55-56, 74-80</b>

### Section 2: Atomic Mass

L1	<ol style="list-style-type: none"> <li>To describe the modern atomic mass scale and explain how atomic masses are determined experimentally (Section 3.1: 3.3).</li> <li>To demonstrate the calculation of the mass percent a given element in a compound (Section 3.4).</li> <li>To demonstrate the calculation of the empirical and molecular formula of a compound (Section 3.5).</li> <li>To show how to obtain the molecular formula, given the empirical formula and the molar mass (Section 3.5).</li> </ol>	<b>Text Sections:</b> 3.1-3.5  <b>Study Guide Sections:</b> 3.1-3.5	<b>Text Pages:</b> 80-99  <b>Study Guide Pages:</b> 42-53
Lab 1	Empirical Formula of Magnesium Oxide		

### Section 3: Stoichiometry

L1	<ol style="list-style-type: none"> <li>To show how to calculate masses of reactants and products using the chemical equation (Section 3.8).</li> <li>To show how to recognize the limiting reactant (Section 3.9).</li> <li>To demonstrate the use of limiting reactant in stoichiometric calculations (Section 3.9).</li> </ol>	<b>Text Sections</b> 3.8-3.9  <b>Study Guide Sections</b> 3.8-3.9	<b>Text Pages:</b> 107-112  <b>Study Guide Pages:</b> 57-61
Lab 12	Gravimetric Analysis		

**Section 4: Precipitation Reactions**

<b>L1</b>	<ol style="list-style-type: none"> <li>To identify precipitation reactions (<b>Section 4.5</b>).</li> <li>To describe reactions in solution by using molecular, complete ionic, and net ionic equations (<b>Section 4.6</b>).</li> </ol>	<b>Text Sections</b>  4.5-4.6  <b>Study Guide Sections</b>  4.5-4.6	<b>Text Pages:</b>  148-155  <b>Study Guide Pages:</b>  81 - 83
<b>Lab 2</b>	Ions in Aqueous Solution		

**Section 5: Oxidation-Reduction Reactions**

<b>L1</b>	<ol style="list-style-type: none"> <li>To characterize oxidation-reduction reactions (<b>Section 4.9</b>).</li> <li>To describe how to assign oxidation states (<b>Section 4.9</b>).</li> <li>To identify oxidizing and reducing agents (<b>Section 4.9</b>).</li> <li>To define the role of the electron in oxidation-reduction reactions (<b>Section 4.9</b>).</li> </ol>	<b>Text Section</b>  4.9  <b>Study Guide Section</b>  4.9	<b>Text Pages:</b>  164-168  <b>Study Guide Pages:</b>  88-91
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**Section 6: Balancing Equations**

<b>L1</b>	<ol style="list-style-type: none"> <li>To describe the half reaction method for balancing redox reactions in acidic and basic conditions (<b>Section 4.10</b>).</li> </ol>	<b>Text Section:</b>  4.10  <b>Study Guide Section:</b>  4.10	<b>Text Pages:</b>  171-178  <b>Study Guide Pages:</b>  91 - 94
<b>Lab 10</b>	Redox Stoichiometry		

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**Topic 2: The Atomic Theory**
**Section 1: Evidence**

<u>L1</u>	1. To summarize the experiments that characterized the structure of the atom (Section 2.1-2.4).	<b>Text Sections:</b> 2.1-2.4  <b>Study Guide Sections:</b> 2.1-2.4	<b>Text Pages:</b> 39-52  <b>Study Guide Pages:</b> 20-23
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**Section 2: Quantum Mechanics**

<u>L1</u>	1. Identify the nature of electromagnetic radiation and carry out calculations in relation to; wavelength, frequency, speed, and energy (Section 7.1). 2. Describe the concept of quantized energy (Section 7.2). 3. To show that light has both wave and particle properties (Section 7.2). 4. To show that the line spectrum of hydrogen demonstrates the quantized nature of the energy of its electron (Section 7.3). 5. To describe the development of the Bohr atom model for the hydrogen atom (Section 7.4).	<b>Text Sections</b> 7. 1-7.4  <b>Study Guide Sections</b> 7. 1-7.4	<b>Text Pages:</b> 288-302  <b>Study Guide Pages:</b> 145-150
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<u>L2</u>	<ol style="list-style-type: none"> <li>1. To show how standing waves can be used to describe electrons in atoms (Section 7.5).</li> <li>2. To describe the Heisenberg uncertainty principle (Section 7.5).</li> <li>3. To explain the significance of electron probability distributions (Section 7.5).</li> </ol>	<b>Text Section:</b>	<b>Text Pages:</b>
		7.5	295-304
		<b>Study Guide Section:</b>	<b>Study Guide Pages:</b>
		7.5	151

<u>L3</u>	<ol style="list-style-type: none"> <li>1. To explain the quantum numbers <math>n</math>, <math>l</math>, and <math>m_l</math> (Section 7.6)</li> <li>2. To describe the shapes of orbitals designated by <math>s</math>, <math>p</math>, <math>d</math>, and <math>f</math> and to discuss orbital energies (Section 7.7).</li> <li>3. To define electron spin and the electron spin, <math>m_s</math>, quantum number (Section 7.8).</li> </ol>	<b>Text Section:</b>	<b>Text Pages:</b>
		7.6-7.8	305-308
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		7.6-7.8	151-153

<u>L4</u>	<ol style="list-style-type: none"> <li>1. State and use the Pauli exclusion principle (Section 7.8).</li> <li>2. State and use the Aufbau principle as a method to represent ground state electron configurations (Section 7.11).</li> <li>3. State and use Hund's rule to determine the ground state electron configuration for an atom or an ion (Section 7.11).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		7. 8-7. 11	310-315
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		7. 8-7. 11	153-158

### Section 3: Periodic Relationships

L1	<ol style="list-style-type: none"> <li>To show general trends in ionizations energy, electron affinity, and atomic radius (Section 7.12).</li> <li>Describe the trend in successive ionization energies for an element in terms of its electronic structure, size, and charge (Section 8.4).</li> </ol>	<b>Text Sections:</b>  7. 11-7. 12 & 8. 4  <b>Study Guide Sections:</b>  7. 11-7. 12 & 8. 4	<b>Text Pages:</b>  318-326 & 355  <b>Study Guide Pages:</b>  155-160, 170-172
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### Topic 3: Chemical Bonding

#### Section 1: Ionic and Covalent Bonds

L1	<ol style="list-style-type: none"> <li>To explain why an ionic bond is formed (Section 8.1).</li> <li>To explain why a covalent bond is formed (Section 8.1).</li> <li>To introduce the polar covalent bond (Section 8.2).</li> <li>To define the relationship between bond polarity (bond dipole) and molecular polarity (polarity) (Section 8.3).</li> <li>To discuss the nature of bonds in terms of electronegativities (Section 8.2).</li> </ol>	<b>Text Sections:</b>  8.1-8.3  <b>Study Guide Sections:</b>  8.1-8.3	<b>Text Pages:</b>  344-349  <b>Study Guide Pages:</b>  166-170
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### Section 2: Intermolecular and Intramolecular Forces

<u>L1</u>	<ol style="list-style-type: none"> <li>To identify and describe the forces acting between particles of solids and liquids according to type; hydrogen bonding, and Van der Waals (Dipole-dipole and London dispersion forces) (Section 10.1).</li> <li>To describe the effect these forces have on the properties of liquids and solids (Section 10.1).</li> <li>To describe some properties of liquids: surface tension, capillary action, and viscosity (Section 10.2).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		10.1-10.2	444-448
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		10.1-10.2	201-203

### Section 3: Molecular Models

<u>L1</u>	<ol style="list-style-type: none"> <li>To show how to write Lewis structures (Section 8.10).</li> <li>Write Lewis structures for special cases (exceptions to the octet rule): B, P, and S (Section 8.11).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		8. 10-8.11	370-377
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		8. 10-8.11	175-178

<u>L2</u>	<ol style="list-style-type: none"> <li>To illustrate the concept of resonance (Section 8.12).</li> <li>To show how to write resonance structures (Section 8.12).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		8. 12	378-384
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		8. 12	179

<u>L3</u>	<ol style="list-style-type: none"> <li>To illustrate the concept of hybridization. (<math>sp^3</math>, <math>sp^2</math>, <math>sp</math>, <math>dsp^3</math>, <math>d^2sp^3</math>) (Section 9.1).</li> <li>To explain bonding capacity in terms of sigma and pi bonds (Section 9.1).</li> </ol>	<b>Text Sections:</b>  9. 1  <b>Study Guide Section</b>  9. 1	<b>Text Pages:</b>  407-420  <b>Study Guide Pages:</b>  190-193
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<u>L4</u>	<ol style="list-style-type: none"> <li>To describe how molecular geometry can be predicted from the number of electron pairs (VSEPR theory) (Section 8.13).</li> <li>To describe and draw geometric structures of molecules and ions (Section 8.13).</li> <li>To illustrate the concept of isomerism using simple organic molecule (Section 8.13).</li> </ol>	<b>Text Section:</b>  8.13  <b>Study Guide Section:</b>  8. 13	<b>Text Pages:</b>  384-396  <b>Study Guide Pages:</b>  182-183
<u>Lab 3</u>	Molecular Geometry		

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### Topic 4: Nuclear Chemistry

#### Section 1: Isotopes, Radioactive Decay and Applications

<u>L1</u>	<ol style="list-style-type: none"> <li>To relate the stability of the nucleus to the number of protons and neutrons (Section 21.1).</li> <li>To classify the type of radioactive decay: alpha particle, beta particle, gamma-particle, positron, and electron capture (Section 21.1).</li> </ol>	<b>Text Sections:</b> 21. 1  <b>Study Guide Sections:</b> 21. 1	<b>Text Pages:</b> 996-998  <b>Study Guide Pages:</b> 413-415
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<u>L2</u>	<ol style="list-style-type: none"> <li>To define and show how to calculate the half-life of a radioactive nuclide (Section 21.2).</li> </ol>	<b>Text Sections:</b> 21. 2  <b>Study Guide Sections:</b> 21. 2	<b>Text Pages:</b> 1001-1005  <b>Study Guide Pages:</b> 416
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<u>L3</u>	<ol style="list-style-type: none"> <li>To show how one element may be changed to another using particle bombardment (Section 21.3).</li> </ol>	<b>Text Sections:</b> 21.3-21.4  <b>Study Guide Sections:</b> 21. 3-21. 4	<b>Text Pages:</b> 1005-1007  <b>Study Guide Pages:</b> 417-419
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## Unit 2: States of Matter.

### Topic 1: Ideal Gases

#### Section 1: Laws and Relationships

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To illustrate the relationship of volume, temperature, pressure, and the amount of gas (Section 5.1).</li> <li>2. To define Boyle's Law, Charles' Law, Avogadro's Law, and the ideal gas law (Section 5.2).</li> <li>3. To perform calculations involving; Boyle's Law, Charles' Law, Avogadro's Law, and the ideal gas law (Section 5.3-5.4).</li> </ol>	Text Sections:	Text Pages:
		5. 1-5. 4	188-204
		Study Guide Sections:	Study Guide Pages:
		5. 1-5. 4	104-114
<u>L2</u>	<ol style="list-style-type: none"> <li>1. To state the relationship between partial pressures and total pressure and between partial pressure and mole fraction (Section 5.5).</li> <li>2. To perform calculations involving partial pressures and vapor pressure (Section 5.5).</li> </ol>	Text Sections:	Text Pages:
		5. 5	205-209
		Study Guide Sections:	Study Guide Pages:
		5. 5	115-116
<u>Lab 4</u>	Ideal Gas Constant Determination		

**Section 2: Kinetic-Molecular Theory**

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To present the basic postulates of the kinetic molecular theory (<b>Section 5.6</b>).</li> <li>2. To describe how real gases deviate from ideal behavior (<b>Section 5.6</b>).</li> <li>3. To describe the dependence of kinetic energy on temperature (<b>Section 5.6</b>).</li> <li>4. Perform calculations involving root mean square velocity (<b>Section 5.6</b>).</li> </ol>	<b>Text Sections:</b>  5. 6  <b>Study Guide Sections:</b>  5. 6	<b>Text Pages:</b>  210-220  <b>Study Guide Pages:</b>  117-118
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<u>L2</u>	<ol style="list-style-type: none"> <li>1. Define effusion and diffusion (<b>Section 5.7</b>).</li> <li>2. To carry out calculations involving effusion and diffusion of a gas (<b>Section 5.7</b>).</li> </ol>	<b>Text Sections:</b>  5. 7  <b>Study Guide Sections:</b>  5. 7	<b>Text Pages:</b>  218-220  <b>Study Guide Pages:</b>  118-120
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**Topic 2: Liquids and Solids**
**Section 1:**

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To define the vapor pressure of a liquid (Section 10.8).</li> <li>2. To discuss the features of heating curves (Section 10.9).</li> <li>3. To discuss the features of phase diagrams; critical points, triple point (Section 10.9).</li> </ol>	<b>Text Sections:</b>  10. 8-10. 9  <b>Study Guide Sections:</b>  10. 8-10. 9	<b>Text Pages:</b>  474-485  <b>Study Guide Pages:</b>  208-210
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**Section 2:**

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To model the structures of ionic solids using the packing of spheres (Section 10.3-10.7).</li> <li>2. To define lattice energy and show how it can be calculated (Section 8.5).</li> </ol>	<b>Text Sections:</b>  10. 3-10. 7 & 8. 5  <b>Study Guide Sections:</b>  10. 3-10. 7 & 8. 5	<b>Text Pages:</b>  470-473 & 357  <b>Study Guide Pages:</b>  203-207, 172-173
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### Topic 3: Solutions

#### Section 1: Solubility

<u>L1</u>	<ol style="list-style-type: none"> <li>1. Identify various types of solutions; gas, liquid, solid, gas-liquid, gas-solid, liquid-solid (Section 11.3).</li> <li>2. To show how molecular structure, pressure, and temperature affect solubility (Section 11.3).</li> </ol>	<b>Text Sections:</b>  11.3 & 11.8  <b>Study Guide Sections:</b>  11.3 & 11.8	<b>Text Pages:</b>  505, 515 - 520 & 537 - 539  <b>Study Guide Pages:</b>  219-221, 228
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#### Section 2: Concentration

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To define various ways of describing solution composition; mass percent, mole fraction, molarity (Section 11.1).</li> </ol>	<b>Text Sections:</b>  11. 1  <b>Study Guide Sections:</b>  11. 1	<b>Text Pages:</b>  506-510  <b>Study Guide Pages:</b>  217-218
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### Section 3: Colligative Properties

<u>L1</u>	<ol style="list-style-type: none"> <li>To show how a solution's vapor pressure is affected by the concentration of solute and the interactions of the solute and solvent (<b>Section 11.2</b>).</li> <li>To calculate vapor pressure using Raoult's law (<b>Section 11.4</b>).</li> </ol>	<b>Text Sections:</b> 11. 2-11. 4  <b>Study Guide Sections:</b> 11. 2-11. 4	<b>Text Pages:</b> 510-520  <b>Study Guide Pages:</b> 218-224
<u>L2</u>	<ol style="list-style-type: none"> <li>To show how colligative properties of electrolyte solutions can be used to characterize the solute (<b>Section 11.5</b>).</li> <li>To explain the effect of a solute on the boiling and freezing points of a solvent (<b>Section 11.5</b>).</li> </ol>	<b>Text Sections:</b> 11. 5  <b>Study Guide Sections:</b> 11. 5	<b>Text Pages:</b> 527-531  <b>Study Guide Pages:</b> 225
<u>L3</u>	<ol style="list-style-type: none"> <li>To explain osmosis and describe its applications (<b>Section 11.6</b>).</li> </ol>	<b>Text Sections:</b> 11. 6  <b>Study Guide Sections:</b> 11. 6	<b>Text Pages:</b> 531-535  <b>Study Guide Pages:</b> 226
<u>Lab 5</u>	Colligative Properties		

<b>Section 4: Non-Ideal Solutions</b>			
<u>L1</u>	1. To explain the behavior of non-ideal solutions (qualitative aspects) (Section 11.4).	<b>Text Sections:</b>	<b>Text Pages:</b>
		11. 4	523-525
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		11. 4	222-224

<b>Unit 3: Reactions</b>			
<b>Topic 1: Equilibria</b>			
<b>Section 1: Equilibrium Constants</b>			
<u>L1</u>	1. To discuss how equilibrium is established (Section 13.1).	<b>Text Sections:</b>	<b>Text Pages:</b>
		13. 1: 13. 3	601-612
	2. To introduce the law of mass action and to show how to calculate values for the equilibrium constant (Section 13.2).	<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
	3. To show how $K$ and $K_p$ are related (Section 13.2).	13. 1-13. 3	258-263

### Section 2: Reaction Movement

L1	<ol style="list-style-type: none"> <li>To show how the equilibrium constant is used to predict the direction a system will move to reach equilibrium (Section 13.5).</li> <li>To calculate the concentration of reactants or product at equilibrium given the equilibrium constant (Section 13.5).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		13.5	615-624
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		13.5	264-267

### Section 3: Calculations

L1	<ol style="list-style-type: none"> <li>To demonstrate the calculation of equilibrium concentrations given initial concentrations (Section 13.5-13.6).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		13.5-13.6	618-630
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		13. 6	267

### Section 4: Behavior of Equilibria

L1	<ol style="list-style-type: none"> <li>To define Le Chatelier's principle (Section 13.7).</li> <li>To show how to predict the changes that occur when a system at equilibrium is disturbed (Section 13.7).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		13.7	630-637
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		13.7	270

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**Topic 2: Acids and Bases**
**Section 1: Concepts and Calculations**

L1	<ol style="list-style-type: none"> <li>To discuss the models of acids and bases: Arrhenius, Bronsted-Lowry, and Lewis (<b>Section 14.1</b>).</li> <li>To define amphoterism (<b>Section 14.2</b>).</li> <li>Identify Arrhenius acid-base reactions (<b>Section 14.1</b>).</li> <li>Identify Bronstead Lowry acid base reactions and identify substances that can behave as Bronsted Lowry acids or bases (<b>Section 14.1</b>).</li> <li>Identify Lewis acid-base reactions and identify substances that can behave as lewis acids aor bases (<b>Section 14.11</b>).</li> </ol>	<b>Text Sections:</b>  14.1, 14.2 & 14.11  <b>Study Guide Sections:</b>  14.1, 14.2 & 14.11	<b>Text Pages:</b>  647-649 & 692-695  <b>Study Guide Pages:</b>  280-283, 300-301
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L2	<ol style="list-style-type: none"> <li>To show how to perform calculations involved in acid-base volumetric analysis (<b>Section 4.8</b>).</li> </ol>	<b>Text Sections:</b>  4. 8  <b>Study Guide Sections:</b>  4. 8	<b>Text Pages:</b>  157-164  <b>Study Guide Pages:</b>  86-88
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<u>L3</u>	1. To interpret titration curves ( <b>Section 15.4</b> ).	Text Sections:  15. 4  Study Guide Sections:  15. 4	Text Pages:  724-728  Study Guide Pages:  317-319
<u>Lab 6</u> Acid-Base Titration			

<b>Section 2: <math>K_a</math> and <math>K_b</math></b>			
<u>L1</u>	1. To relate acid strength to the position of the dissociation equilibrium ( <b>Section 14.1-14.2</b> ). 2. To discuss the autoionization of water ( <b>Section 14.2</b> ). 3. To define pH, pOH, and pK ( <b>Section 14.3</b> ).	Text Sections:  14.1-14.3  Study Guide Sections:  14. 1: 14. 3	Text Pages:  650-658  Study Guide Pages:  280-285

<u>L2</u>	1. To calculate values of $K_a$ and $K_b$ for weak acids/bases ( <b>Section 14.5</b> ).	Text Sections:  14. 5-14. 7  Study Guide Sections:  14. 5 A,B,C,D 14. 6 A & B	Text Pages:  660-676  Study Guide Pages:  287-291, 291-293
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**Section 3:**

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To account for the acidity or basicity or neutrality of aqueous solutions of salts in terms of hydrolysis of anions and cations (<b>Section 14.8</b>).</li> <li>2. To study the effect of a common ion on acid dissociation equilibria (<b>Section 15.1</b>).</li> </ol>	<b>Text Sections:</b>  <b>14. 8 &amp; 15. 1</b>  <b>Study Guide Sections:</b>  <b>14. 8 &amp; 15. 1</b>	<b>Text Pages:</b>  <b>683 &amp; 708-710</b>  <b>Study Guide Pages:</b>  <b>296 &amp; 309</b>
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<u>L2</u>	<ol style="list-style-type: none"> <li>1. To explain the characteristics of buffered solutions (<b>Section 15.2</b>).</li> <li>2. To show how to calculate a buffer pH given the concentrations of the buffering materials (<b>Section 15.2</b>).</li> <li>3. To describe the meaning of buffer capacity (<b>Section 15.3</b>).</li> </ol>	<b>Text Sections:</b>  <b>15. 2-15. 3</b>  <b>Study Guide Sections:</b>  <b>15. 2 A-C 15. 3 A-B</b>	<b>Text Pages:</b>  <b>710-721</b>  <b>Study Guide Pages:</b>  <b>310 &amp; 316</b>
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**Section 4: Solubility Properties**

<u>L1</u>	<ol style="list-style-type: none"> <li>To show how to calculate the solubility product of a salt given its solubility and vice versa (<b>Section 15.6</b>).</li> <li>To demonstrate the prediction of relative solubilities from <math>K_{sp}</math> values (<b>Section 15.6</b>).</li> </ol>	<b>Text Sections:</b>  15.6  <b>Study Guide Sections:</b>  15.6 A, B, C & D	<b>Text Pages:</b>  745-750  <b>Study Guide Pages:</b>  325-328
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<u>L2</u>	<ol style="list-style-type: none"> <li>To explain the effect of pH and a common ion on the solubility of a salt (<b>Section 15.7</b>).</li> <li>To show how to predict if a precipitation will occur when solutions are mixed (<b>Section 15.7</b>)</li> </ol>	<b>Text Sections:</b>  15.7  <b>Study Guide Sections:</b>  15.7 A & B	<b>Text Pages:</b>  755-758  <b>Study Guide Pages:</b>  328-330
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### Topic 3: Kinetics

#### Section 1: Reaction Rate

L1	<ol style="list-style-type: none"> <li>To define reaction rate and to show how rates can be measured from experimental data (Section 12.1).</li> <li>To describe the two types of rate laws (Section 12.2).</li> </ol>	<b>Text Sections:</b>  12. 1-12. 3  <b>Study Guide Sections:</b>  12. 1 A & B- 12. 3	<b>Text Pages:</b>  551-561  <b>Study Guide Pages:</b>  235-241
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#### Section 2: Rate Laws

L1	<ol style="list-style-type: none"> <li>To learn methods for determining the rate law for a reaction (Section 12.3).</li> </ol>	<b>Text Sections:</b>  12.3  <b>Study Guide Sections:</b>  12.3 A & B	<b>Text Pages:</b>  557-561  <b>Study Guide Pages:</b>  237-241
Lab 8	Rate Laws		

### Section 3: Reaction Rate Determinants

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To discuss the temperature dependence of reaction rates.</li> <li>2. To describe the collision model (Section 12.7).</li> <li>3. To define and show how to calculate activation energy (Section 12.7).</li> <li>4. To explain how a catalyst speeds up a reaction (Section 12.8).</li> <li>5. To discuss applications of catalysts (Section 12.8).</li> </ol>	<b>Text Sections:</b> 12. 7 & 12. 8  <b>Study Guide Sections:</b> 12.7 & 12.8	<b>Text Pages:</b> 576 & 248  <b>Study Guide Pages:</b> 248-251
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### Section 4: Reaction Mechanisms

<u>L1</u>	<ol style="list-style-type: none"> <li>1. To define the rate determining step (Section 12.6).</li> <li>2. To define reaction mechanism (Section 12.6).</li> <li>3. To investigate the relationship between the reaction pathway and the rate law (Section 12.6).</li> </ol>	<b>Text Sections:</b> 12. 6  <b>Study Guide Sections:</b> 12. 6 A & B	<b>Text Pages:</b> 573-576  <b>Study Guide Pages:</b> 246-248
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## Topic 4: Thermodynamics

### Section 1: Enthalpy

<u>L1</u>	<ol style="list-style-type: none"> <li>To describe the characteristics of state functions (<b>Section 6.1</b>).</li> <li>To describe the energy flow between a system and its surroundings (<b>Section 6.1</b>).</li> <li>To discuss the first law of thermodynamics (<b>Section 6.1</b>).</li> <li>To show how to calculate the work that results from changing the volume of a gas at constant pressure (<b>Section 6.1</b>).</li> </ol>	Text Sections:	Text Pages:
		6. 1	240-244
		Study Guide Sections:	Study Guide Pages:
		6. 1	130

<u>L2</u>	<ol style="list-style-type: none"> <li>To define enthalpy and demonstrate calculations of the change in enthalpy in a chemical reaction (<b>Section 6.2</b>).</li> <li>To show how the change in enthalpy is measured by calorimetry (<b>Section 6.2</b>).</li> </ol>	Text Sections:	Text Pages:
		6. 2	246-248
		Study Guide Sections:	Study Guide Pages:
		6. 2	133-136

<u>L3</u>	<ol style="list-style-type: none"> <li>To discuss the characteristics of enthalpy changes (<b>Section 6.3</b>).</li> <li>To show how to calculate H for a chemical reaction (<b>Section 6.3</b>).</li> <li>To define standard states (<b>Section 6.4</b>).</li> <li>To show how to use standard enthalpies of formation to calculate H<sub>o</sub> for a reaction (<b>Section 6.4</b>).</li> <li>To show how bond energies can be used to calculate heats of reaction. (<b>Section 8.8</b>)</li> </ol>	Text Sections:	Text Pages:
		6. 3-6. 4 & 8. 8	254-258 & 366-369
		Study Guide Sections:	Study Guide Pages:
		6. 3-6. 4 & 8. 8	136 & 174

L4	<ol style="list-style-type: none"> <li>To show how to calculate heats of vaporization and fusion (<b>Section 10.8</b>).</li> <li>To discuss applications of thermochemistry (<b>Section 6.5-6.6</b>).</li> </ol>	<b>Text Sections:</b>  10. 8 & 6.5-6.6  <b>Study Guide Sections:</b>  10. 8	<b>Text Pages:</b>  474 & 265  <b>Study Guide Pages:</b>  208-209
Lab 9	Thermodynamics		

### Section 2: Entropy and Free Energy

L1	<ol style="list-style-type: none"> <li>To define a spontaneous process (<b>Section 16.1</b>).</li> <li>To define entropy in terms of positional probability.</li> <li>To state the second law of thermodynamics (<b>Section 16.2</b>).</li> <li>To discuss the important characteristics of entropy changes in the surroundings (<b>Section 16.2</b>).</li> <li>To apply the relationship between <math>S_{\text{sur}}</math>, <math>H</math>, and <math>T</math> (Kelvin) (<b>Section 16.3</b>).</li> </ol>	<b>Text Sections:</b>  16. 1-16. 3  <b>Study Guide Sections:</b>  16. 1-16. 3	<b>Text Pages:</b>  778-785  <b>Study Guide Pages:</b>  340-343
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<u>L2</u>	<ol style="list-style-type: none"> <li>To define free energy and relate it to spontaneity (<b>Section 16.4</b>).</li> <li>To apply positional probability to chemical reactions (equilibrium) (<b>Section 16.4</b>).</li> <li>To relate molecular complexity to entropy (<b>Section 16.4</b>).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		16. 4	788-790
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		16. 4	344-345

<u>L3</u>	<ol style="list-style-type: none"> <li>To relate molecular complexity to entropy (<b>Section 16.5</b>).</li> <li>To calculate entropy for chemical reactions (<b>Section 16.5</b>)</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		16.5	791-795
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		16. 5	345-346

<u>L4</u>	<ol style="list-style-type: none"> <li>To show how to calculate the standard free energy change in a chemical reaction (<b>Section 16.6</b>).</li> <li>To define standard free energy of formation and show how to use it to predict spontaneity (<b>Section 16.6</b>).</li> </ol>	<b>Text Sections:</b>	<b>Text Pages:</b>
		16. 6	795-800
		<b>Study Guide Sections:</b>	<b>Study Guide Pages:</b>
		16. 6	347-349

### Section 3: Thermochemistry and Electrochemistry

L1	<ol style="list-style-type: none"> <li>1. To define equilibrium in terms of minimum free energy (Section 16.8).</li> <li>2. To show how the value of K is related to <math>G^\circ</math> (Section 16.8).</li> <li>3. To show how the value of <math>E^\circ</math> is related to <math>G^\circ</math> (Section 17.3).</li> </ol>	<b>Text Sections:</b>  16. 8 & 17. 3  <b>Study Guide Sections:</b>  16. 8	<b>Text Pages:</b>  804 & 831  <b>Study Guide Pages:</b>  350-352
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### Topic 5: Electrochemistry

#### Section 1: Concepts

L1	<ol style="list-style-type: none"> <li>1. To define the components of an electrochemical cell (Section 17.1).</li> <li>2. To distinguish between a galvanic and an electrolytic cell (Section 17.1).</li> <li>3. To define cell potential (Section 17.1).</li> </ol>	<b>Text Sections:</b>  17.1  <b>Study Guide Sections:</b>  17.1	<b>Text Pages:</b>  822-823 & 829  <b>Study Guide Pages:</b>  358-359
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<u>L2</u>	<ol style="list-style-type: none"> <li>1. To describe how standard reduction potentials are assigned in terms of the standard hydrogen electrode (<b>Section 17.2</b>).</li> <li>2. To demonstrate the combination of half-reactions to form the cell reaction (<b>Section 17.2</b>)</li> <li>3. To characterize a galvanic cell (<b>Section 17.2</b>).</li> </ol>	<b>Text Sections:</b>  17.2  <b>Study Guide Sections:</b>  17.2	<b>Text Pages:</b>  824 - 829  <b>Study Guide Pages:</b>  359 - 363
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<u>L3</u>	<ol style="list-style-type: none"> <li>1. To relate the maximum cell potential to the free energy difference between cell reactants and products (<b>Section 17.3</b>).</li> <li>2. To calculate the net cell voltage of a cell with non-standard concentrations using the Nernst equation. (<b>Section 17.4</b>).</li> </ol>	<b>Text Sections:</b>  17. 3-17. 4  <b>Study Guide Sections:</b>  17. 3 A-B & 17. 4 A-E	<b>Text Pages:</b>  831-835  <b>Study Guide Pages:</b>  363 368
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<u>L4</u>	<ol style="list-style-type: none"> <li>1. Discuss applications of electrochemistry; batteries, corrosion (<b>Section 17.5-17.6</b>).</li> </ol>	<b>Text Sections:</b>  17. 5-17. 6  <b>Study Guide Sections</b>  17. 5-17. 6	<b>Text Pages:</b>  841-847  <b>Study Guide Pages:</b>  368-369
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<u>L5</u>	1. To describe the stoichiometry of electrolysis reactions (Section 17.7).	<b>Text Sections:</b>  17. 7  <b>Study Guide Sections:</b>  17. 7	<b>Text Pages:</b>  847-853  <b>Study Guide Pages:</b>  369-371
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<u>L6</u>	1. To show how to predict the order of electrolysis of the components of a mixture (Section 17.7). 2. To discuss applications of electrolysis (Section 17.8).	<b>Text Sections:</b>  17. 7-17. 8  <b>Study Guide Sections:</b>  17. 7-17. 8	<b>Text Pages:</b>  851-860  <b>Study Guide Pages:</b>  369-371
<u>Lab 11</u>	Electrochemistry		

**Appendix C: Lessons.**

### *Curriculum Outcomes*

1. To describe the modern atomic mass scale and explain how atomic masses are determined experimentally.
2. To demonstrate the calculation of the mass percent a given element in a compound.
3. To demonstrate the calculation of the empirical and molecular formula of a compound.
4. To show how to obtain the molecular formula, given the empirical formula and the molar mass.

● Lab 1**Section 2****Lesson 1: Determination of Atomic Masses by Chemical and Physical Means**

## REFERENCE

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- Text Sections 3.1 - 3.5, pp. 80 - 99
- Study Guide Sections 3.1 - 3.5, pp. 42 - 53

**Atomic Mass**

In nature many isotopes exist for each atom. Each isotope has a different mass (protons + neutrons). The atomic mass expressed in the periodic table is simply an *average* mass of all isotopes for that atom. Inserting a small sample in a mass spectrometer (a precise machine that measures relative masses) we can determine the % abundance of each isotope:

Carbon-12 ( $C^{12}$ ) is 98.89% and  $C^{13}$  is 1.11% of all isotopes of carbon. The remaining percentages would be  $C^{14}$  and other isotopes of carbon.

Carbon-12 has 6 protons and 6 neutrons and should weigh 12 atomic mass units (AMU).

Carbon-13 has 6P and 7N and should weigh 13 AMU.

$$\begin{aligned}
 \text{Average mass} &= \sum (\% \text{abundance} \times \text{AMU}) \\
 &= 98.89\%(12) + 1.11\%(13) \\
 &= 12.01 \text{ amu} \\
 &\text{or } 12.01 \text{ g/mol}
 \end{aligned}$$

- Sample exercise 3.1 p. 82
- Study Guide 3.1 A, B p. 42

**Percent Composition**

Percent composition is simply a method used to report the make up of a compound. There are three steps:

1. Calculate the molar mass of the compound.
2. Calculate the total mass for each atom.
3. Divide each elements mass by the total mass.

What is the percent composition of each atom in a molecule of methane?



1. Calculate the molar mass of  $\text{CH}_4$

$$1 \times \text{C} = 1 \times 12.01 = 12.01$$

$$4 \times \text{H} = 4 \times 1.01 = \underline{4.04}$$

$$16.05 \text{ g/mol}$$

2. Calculate the mass for each atom

Mass from C

$$1 \times 12.01 = 12.01$$

Mass from H

$$4 \times 1.01 = 4.04$$

3. Divide each mass by the total mass.

$$\begin{aligned} \% \text{Carbon} &= \frac{\text{mass}_C}{\text{mass}_{\text{total}}} \times 100\% & \% \text{Hydrogen} &= \frac{\text{mass}_H}{\text{mass}_{\text{total}}} \times 100\% \\ &= \frac{12.01}{16.05} \times 100\% & &= \frac{4.04}{16.05} \times 100\% \\ &= 74.88\% & &= 25.17\% \end{aligned}$$

Check:

$$\% \text{C} + \% \text{H} = 100\%$$

$$74.88\% + 25.17\% = 100\%$$

- Sample exercise 3.9 and 3.10; p. 91
- Study Guide 3.4 A; p. 49

## Finding the Empirical Formula of a Compound

An empirical formula is the simple whole number ratio of the atoms in a compound. There are three steps:

1. If no mass is given, assume 100 g.
2. Calculate the moles of each atom.
3. Find the simplest whole number ratio by dividing each mole quantity by the smallest value.

Find the empirical formula of a compound that is 40.00% C, 6.71% H, and 53.29% O.

1. Assuming 100g (we could assume any mass but 100 g is the most convenient.)

Therefore:

$$\begin{aligned}\text{mass C} &= 40.00\% \times 100 \text{ g} \\ &= 40.00 \text{ g}\end{aligned}$$

$$\text{mass H} = 6.71 \text{ g}$$

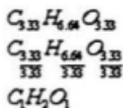
$$\text{mass O} = 53.29 \text{ g}$$

2. Calculate moles of each

$$\begin{array}{lll}n = \frac{m}{M} & n = \frac{m}{M} & n = \frac{m}{M} \\ n_{\text{C}} = \frac{m_{\text{C}}}{M_{\text{C}}} & n_{\text{H}} = \frac{m_{\text{H}}}{M_{\text{H}}} & n_{\text{O}} = \frac{m_{\text{O}}}{M_{\text{O}}} \\ = \frac{40.00\text{g}}{12.01\text{g/mol}} & = \frac{6.71\text{g}}{1.0\text{g/mol}} & = \frac{53.29\text{g}}{16.00\text{g/mol}} \\ = 3.33 \text{ mol of carbon} & = 6.54 \text{ mol of hydrogen} & = 3.33 \text{ mol of oxygen}\end{array}$$

! Note: we divide by the atomic mass *not* the molecular mass. That is, divide by the molar mass of H and not H<sub>2</sub>

3. Find the simplest whole number ratio and hence, the empirical formula.



If the molar mass of the substance were given we could then get the molecular formula for the compound. Let's say the molar mass of the above was found to be 180.18 g/mol. What would be the molecular formula?

We simply get the molar mass of our empirical formula:

$$\text{Molar mass of } CH_2O = 30.03 \text{ g/mol}$$

Get the ratio of the molecular molar mass to the empirical molar mass:

$$\begin{aligned} \#units &= \frac{MM \text{ of compound}}{MM \text{ of emp. form}} \\ &= \frac{180.18}{30.03} \\ &= 6 \end{aligned}$$



- Sample exercise 3.11, 3.12, 3.13; p. 96.
- Study Guide 3.5 A, B, C; p. 51.

### CD-ROM Ch. 3: Problem set: Mass Percent

Practice Questions: p. 126 #'s 49, 51, 53, 55, 57, 59, 61, 65, 67 & 71

• [Lab 1](#)



file://D:\apchemistry\units\unit 1\topic 1\section 5\lesson 1\outcomes.htm

### *Curriculum Outcomes*

1. To characterize oxidation-reduction reactions.
2. To describe how to assign oxidation states
3. To identify oxidizing and reducing agents.
4. To define the role of the electron in oxidation-reduction reactions

## ● Lab 10



## Section 5

### Lesson 1: Oxidation - Reduction Reactions

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- Text Section 4.9; pp. 164 - 168
- Study Guide Section 4.9; pp. 88 - 91

Oxidation-reduction reactions involve the transfer of electrons from one species to another. The species that loses electrons is said to be *oxidized*.

**LEO is an OX – Loss of Electrons is Oxidation**

The species that gains electrons is said to be *reduced*.

**GER – Gain Electrons is Reduction**

Or

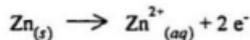
**OIL RIG – Oxidation Involves Loss – Reduction Involves Gain**

In order for an oxidation-reduction reaction to take place, we need both process to occur. That is, we cannot have oxidation with out reduction. Why not?

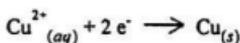
Consider the following net ionic equation:



The corresponding half reactions would be:



Zn(s) lost 2 electrons (thus Zn(s) was oxidized.)



$\text{Cu}^{2+}$  gained 2 electrons (thus  $\text{Cu}^{2+}$  was reduced.)

In this case, the electrons were transferred from zinc to copper.  $\text{Zn}(s)$  was oxidized by  $\text{Cu}^{2+}$  so we say that  $\text{Cu}^{2+}$  was an *oxidizing agent*. Similarly we can say that  $\text{Zn}(s)$  was acting as the *reducing agent*. Why?

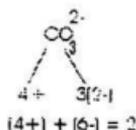
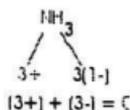
Redox reactions are not always this simple or easy to identify. We need to be able to recognize if reduction and oxidation have occurred. To do this we have to assign oxidation states to all species involved in the reaction.

- See Table 4.2; p 167: Rules for assigning oxidation numbers.

Simply:

Species	Oxidation Number
Elements	0
Mono-atomic ions	Their charge (i.e.: $\text{Na}^{+}$ - OX# = 1+)
Bonded oxygen	-2 (except when in $\text{H}_2\text{O}_2$ )
Bonded hydrogen	+1
Fluorine	-1

The net charge of a poly-atomic species must be zero.



- Sample exercises 4.16, 4.17, 4.18; p. 167.
- Study Guide examples: 4.9 A, B, C; p. 89.

 CD-ROM Ch. 4: Exploration: Problem Set

**Practice Questions:**

p. 182: #'s 53, 55, 57 & 79

p. 863: #'s 14 & 15

---

● Lab 10



### *Curriculum Outcomes*

1. To explain why an ionic bond is formed.
2. To explain why a covalent bond is formed.
3. To introduce the polar covalent bond.
4. To define the relationship between bond polarity (bond dipole) and molecular polarity (polarity).
5. To discuss the nature of bonds in terms of electronegativities.



---

## Section 1

### Lesson 1: Binding Forces, Polarity of Bonds and Electronegativities

#### REFERENCE

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- Text Sections 8.1 - 8.3; pp. 344 - 349
  - Study Guide Sections 8.1 - 8.3; pp. 166 - 170
- 

#### The Chemical Bond

A chemical bond forms when *a simultaneous attraction exists between the electrons and the nuclei of two or more atoms*. The "strongest" chemical bonds are those which result in the formation of noble gas structures (octets) for the atoms involved.

#### The Ionic Bond

- A bond between atoms (or molecules) that lose electrons easily with atoms (or molecules) that gain electrons easily.
- It is usually found between a metal and a non-metal.

#### The Covalent Bond

- A bond formed by the sharing of electrons by two nuclei
  - *Non-polar covalent* bonds involve the equal sharing of electrons by two nuclei while *polar covalent* bonds involve unequal sharing of electrons by two or more different nuclei.
  - The strength of such bonds is a direct function of the difference in electronegativity between the atoms. Electronegativity is referred to as *electron attracting* ability. Linus Pauling developed an arbitrary scale in which fluorine is assigned the highest value of 4.0 and all the other elements somewhat less.
- See Text: Figure 8.3; p. 348.

### Bond Polarity and Dipole Moments

## Electron cloud

In polar covalent compounds, somewhat of a charge separation occurs. The more electronegative atoms seem to attract the electrons more strongly and as a result we see a region of higher electron density giving an apparent *negative* influence and leaving the weaker atom with an apparent deficiency of electrons (or *positive* influence).



Some polar covalent compounds with bond dipoles illustrated. Note that bond dipole arrows point to the more electronegative element and, thus, the element with the greater electron attracting ability. See the image to the right to appreciate this.

### H<sub>2</sub>O

- [Bond dipoles](#)
- [Bond dipoles and the resultant dipole moment](#)

### NH<sub>3</sub>

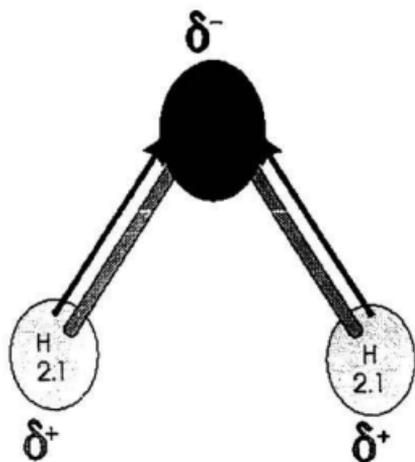
- [Bond dipoles](#)
- [Bond dipoles and the resultant dipole moment](#)

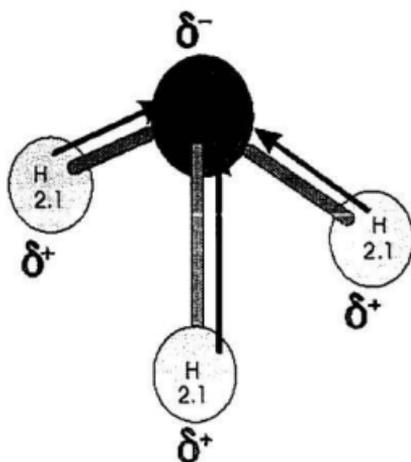
 [Video: Bending of Water](#)

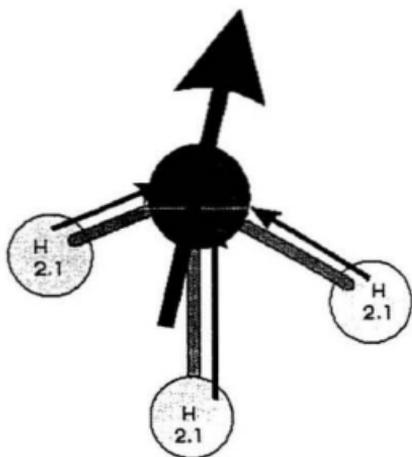
 CD-ROM Ch. 8: Problems set

Practice Questions:p. 399: #'s 15, 17, 21, 22 & 92









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### *Curriculum Outcomes*

1. To illustrate the relationship of volume, temperature, pressure, and the amount of gas.
2. To define Boyle's Law, Charles' Law, Avogadro's Law, and the ideal gas law.
3. To perform calculations involving; Boyle's Law, Charles' Law, Avogadro's Law, and the ideal gas law.

## ● Lab 4



## Section 1

### Lesson 1: Laws of Ideal Gases

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- Text Sections 5.1 - 5.4; pp. 188 - 204
- Study Guide Sections 5.1 - 5.4; pp. 104 - 114

*This section is a review of Chemistry 2202 with the exception of gas densities.*

### Gas Laws

#### Boyle's Law

Boyle's law states that pressure is inversely proportional to volume:

$$P \propto \frac{1}{V}$$

Simply put, if pressure increases then the volume will decrease, or if the pressure is decreased then the volume will increase.

 [Video: Boyle's Law](#)

• **Figure 5.5; p. 191**

$$P_1V_1 = P_2V_2 \text{ At a constant temperature (K) and moles of gas (n)}$$

#### Charles' Law

Charles' Law states that the volume of a gas is proportional to its temperature

$$V \propto T$$

If the temperature of a gas is increased the volume will increase proportionally.

• Figure 5.8; p. 194

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{At a constant pressure (P) and number of moles (n)}$$

Note: Temperatures used must be absolute, that is they must be in Kelvin  $K = ^\circ C + 273.15$

#### Avogadro's Law

Avogadro's Law states that the volume of a gas is proportional to the amount of the gas present.

$$V \propto n \quad \text{At a constant pressure (P) and temperature (K)}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad \text{At a constant temperature (K) and pressure (P)}$$

At STP (standard temperature and pressure), 1 mole of any gas occupies 22.4 L.  $V_{sp} = 22.4 \text{ L/mol}$  What are STP conditions?

#### The Ideal Gas Law

Combination of all three above laws:

$$PV = nRT \quad \text{Where:}$$

$R$  is the ideal gas constant.  
 $n$  is the number of moles of gas

#### Molar Mass Determination

$$n = \frac{m}{M}$$

Substitute the above equation into the ideal gas equation:

$$PV = \frac{mRT}{M}$$

$$M = \frac{mRT}{PV}$$

#### Gas Density

$$\begin{aligned}d &= \frac{m}{V} \\ &= \frac{nM}{V} \\ d &= \frac{PM}{RT}\end{aligned}$$

We can rearrange to get another equation to determine molar mass:

$$M = \frac{dRT}{P}$$

---

 **CD-ROM Ch.5: Animation of gas laws**

**Video**

**Problem sets: Boyle's Law, Charles' Law, Ideal Gas Law and Avogadro's Law.**

**Practice Questions:**

p. 230: #'s 14, 15, 19, 27, 29, 31, 33, 35 & 43 [gas laws]

p. 230: #'s 45, 47, 55, 57, 101 & 105 [density]

p. 230: #'s 49, 51 & 53 [gas stoichiometry]



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### *Curriculum Outcomes*

1. Define effusion and diffusion.
2. Carry out calculations involving effusion and diffusion of a gas.



---

## Section 2

### Lesson 2: Effusion and Diffusion

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- Text Section 5.7; pp. 218
  - Study Guide Section 5.7; pp. 118 - 120
- 

#### Diffusion

Diffusion is the mixing of gases.

Think of a situation when *Joe Cool* walks in the room stinking of two dollar cologne(perfume). The cologne is evaporating into the gaseous phase and the molecules enter our nose and we smell the fragrance. Joe's perfume will first be smelt by those closest to him and will eventually spread out in the room until everyone can smell it. The perfume molecule is slow to fill the room because it is colliding and mixing with all the other gas molecules in the room. Depending how much perfume he is wearing, eventually the perfume will diffuse to fill the room.

#### Effusion

Effusion is the passage of gas through a tiny hole into a vacuum.

Eventually cool Joe's fragrant smell will diminish as the perfume molecules escape around the cracks of the doors, windows, ceiling, etc.. Remember all gases try to fill their container. If the container is not sealed, the gas will eventually escape. In the case of Joe Cool, we are grateful for effusion!

This very situation was considered and *Graham's Law of Diffusion/Effusion* was developed.

#### **Graham's Law**

Graham's Law states that the rate (speed) of diffusion of two different gases are inversely

proportional to the square roots of their molar masses:

$$\frac{\text{Rate of Effusion gas}_A}{\text{Rate of Effusion gas}_B} = \sqrt{\frac{M_B}{M_A}}$$

We can simply say, lighter gases effuse or diffuse (whichever may be the case) faster. This would be consistent with the ideas expressed with the KMT on ideal gases. Smaller (lighter) gas molecules would have fewer interactions, thus can move faster.

i.e.:  $\text{H}_2$  moves faster than He

Graham's law also holds true for five quantities, we can simply replace any one of the five for rate in Graham's law:

1. Molecular speeds
2. Rate of effusion (or diffusion)
3. Effusion times
4. Distance traveled
5. Amount of gas effused

So, for example:

$$\frac{\text{moles of gas}_A}{\text{moles of gas}_B} = \sqrt{\frac{M_B}{M_A}}$$

- Sample exercises 5.20; p. 219.
- Study Guide 5.7; p. 119.

 CD-ROM Ch. 5: Animation: Diffusion, Effusion.

Practice Questions: p. 234: #'s 79, 81 & 109



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### *Curriculum Outcomes*

1. To define various ways of describing solution composition; mass percent, mole fraction, molarity.



## Section 2

### Lesson 1: Reporting Concentration

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- Text Section 11.1; pp. 506 - 510
- Study Guide Section 11.1

When reporting concentration various methods are available. The method used depends on the application involved.

#### 1. Molarity (M)

Molarity is really the same thing as concentration and is typically given units of mol/ L.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution}}$$

$$M = \frac{n}{V}$$

#### 2. Mass Percent

Mass percent is often called *weight percent*. It has no units because it is given as a percent.

$$\text{mass percent} = \left( \frac{\text{mass of solute}}{\text{mass of solution}} \right) \times 100\%$$

#### 3. Mole fraction (X)

Mole fraction is the ratio of the number of moles of solute to the number of moles of solvent.

$$\text{mole fraction of A} = \chi_A = \frac{n_A}{n_{\text{total}}}$$

#### 4. Molality (m)

Molality is the number of moles of solute per kilogram of solvent; it has units of mol/kg.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kilograms of solvent}}$$

$$m = \frac{n}{\text{mass}_{\text{(of solvent in kg)}}}$$

There are other methods such as **Normality**, **Parts per million (PPM - # molecules of solution per 1 million particles of solvent)**, **Parts per trillion (PPT)**, etc. However these are not dealt with in this course (Phew!).

- **Sample exercises 11.1, 11.2; p. 506.**
- **Study Guide 11.1 A; p. 217.**

 **CD-ROM Ch. 11: Problem sets**

**Practice Questions: p. 542: #'s 27, 29, 31, 33 & 79**



*Curriculum Outcomes*

1. To relate the stability of the nucleus to the number of protons and neutrons.
2. To classify the type of radioactive decay: alpha particle, beta particle, gamma-particle, positron, and electron capture.



## Section 1

### Lesson 1: Nuclear Equations

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• Text Section 21.1; pp. 996 - 998

• Study Guide Section 21.1; pp. 413 - 415

### Isotope Notation



Where:

Z = atomic number (# of protons)

A = mass number (protons + neutrons)

X = atomic symbol

### The Elementary Particles of Atoms

#### Protons

- ${}^1_1p$  or  ${}^1_1H$ .
- Protons are positively charged and are found in the nucleus of the atom.

#### Neutrons

- ${}^1_0n$ .
- Neutrons have no charge and are also found in the nucleus.

Protons and neutrons make up the mass of the atom. The sum of the protons and neutrons is the mass number (A).

#### Electrons

- ${}_{-1}^0e$
- Electrons are negatively charged. They are found in the space surrounding the nucleus.
- In a neutral atom the number of electrons is the same as the number of protons. Electrons have a very small mass.

## Radioactive decay

Radioactive decay is a natural process, which involves reactions of the nucleus; therefore we must clearly state the isotope form of the atom. There are *three* distinct types of particles that can be emitted (given off) during the nuclear decay process:

### 1. Alpha particles

- ${}^4_2He$
- Alpha particles are essentially helium nuclei. They consist of 2 protons and 2 neutrons - but no electrons. As a result, they have a positive 2 charge.
- Alpha particles produce large number of ions as they move through matter but have relatively low penetrating power. (They can be stopped by a sheet of paper!).

### 2. Beta particles

- $\beta^-$  or  ${}^0_{-1}B$  or  ${}_{-1}^0e$
- Beta particles are electrons, which are ejected from the nucleus after some kind of transformation of a neutron into a proton and electron. They have the same properties as electrons, including the negative charge and insignificant mass.
- Beta particles have low ionizing power but great penetrating power.

### 3. Gamma rays

- $\gamma$  (gamma)
- Gamma rays are very high-energy electromagnetic radiation. Like visible light, they have very little mass associated with them.
- They are generally not written as part of nuclear reactions although they are released during many. To some extent they account for small mass losses which occur during nuclear reactions. (Remember Einstein  $E = mc^2$ )

### 4. Positron

- $\beta^+$ ,  ${}^0_{+1}B$  or  ${}^0_{+1}e$
- The positron is very similar to a beta particle except it has a positive

charge. It occurs when a proton is converted to a neutron.

- The positron has the same properties as an electron but it has a positive charge.

## Rules for Nuclear Booking

1. The sum of the mass numbers must be equal
2. The sum of the atomic numbers must be equal.

## Types of Nuclear Decay

### 1. Alpha Decay

- ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He}$
- The uranium-238 nuclide decays to produce an alpha particle and an isotope with atomic number 90: Thorium-234.

### 2. Beta Decay

- ${}_0^1\text{n} \rightarrow {}_1^1\text{p} + {}_{-1}^0\text{e} + \gamma$
- This equation shows a neutron being converted to a proton and a beta particle with energy (gamma). We don't normally write this part.
- ${}_{90}^{234}\text{Tl} \rightarrow {}_{91}^{234}\text{Pb} + {}_{-1}^0\text{e}$

### 3. Positron Emission

- ${}_1^1\text{p} \rightarrow {}_0^1\text{n} + {}_1^0\text{e} + \gamma$
- This equation shows the conversion of a proton to a neutron and a positron. We do not usually write this.
- ${}_{15}^{30}\text{P} \rightarrow {}_{14}^{30}\text{Si} + {}_1^0\text{e}$

### 4. Electron Capture

- Electron capture involves the process of capturing an inner electron by the isotope and combining it with a proton to produce a neutron.
- ${}_{-1}^0\text{e} + {}_1^1\text{p} \rightarrow {}_0^1\text{n} + \gamma$  We don't usually write this
- ${}_{80}^{201}\text{Hg} + {}_{-1}^0\text{e} \rightarrow {}_{79}^{201}\text{Au}$  Mercury to Gold!! The Alchemist's Dream. Imagine..!

• Applet: [Radioactive Decay](#). Please note that sometimes these applets may be time-consuming to download. If this is the case, stop the downloading process, close the window and try again some other time.

- Sample exercises 21.1 and 21.2 p. 1000.
  - Study Guide examples: 21.1 A, B, and C; p. 414.
- 

 CD-ROM Ch. 21

Practice Questions: p. 1028: #'s 9, 11, 13, 15 & 17

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### *Curriculum Outcomes*

1. Account for the acidity or basicity or neutrality of aqueous solutions of salts in terms of hydrolysis of anions and cations.
2. To study the effect of a common ion on acid dissociation equilibria.



## Section 3

### Lesson 1: Hydrolysis and the Common Ion Effect

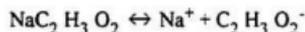
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- Text Sections 14.8; p. 683 & 15.1; pp. 708 - 710
- Study Guide Section 14.8; pp. 296 & 15.1; p. 309

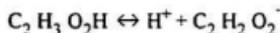
#### Hydrolysis

Acids and bases react to form salts in a reaction known as *neutralization*. The solutions produced are not always at pH 7. In fact, any given salt dissolved in water will not always give a solution with pH 7.

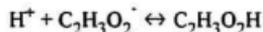
Consider the case of sodium acetate, the salt of sodium hydroxide (a **STRONG** base) and acetic acid (a **WEAK** acid):



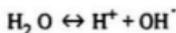
- This dissociation initially occurs 100% since this is a very soluble salt. But remember that acetic acid is a **WEAK** acid which breaks up in water only a little bit:



- Since the  $K_a$  for this reaction is quite small the equilibrium in this reaction lies far to the left. Thus, if acetate ions are added to a water solution, it is reasonable to expect some of them to combine with the small number of hydrogen ions available ( $1 \times 10^{-7}$  M) and form acetic acid molecules. These two reactions now occur simultaneously:



And to replace the  $\text{H}^+$  removed from the water as acetic acid:



- However, there is already  $\text{OH}^-$  present in water (not very much though!). With this reaction, now, there is more. Therefore, a solution of sodium acetate is slightly basic ( $\text{pH} > 7$ ). This phenomenon is called hydrolysis and there are four possible cases:
  1. Salt of STRONG acid + STRONG base = neutral solution
  2. Salt of STRONG acid + WEAK base = acidic solution
  3. Salt of WEAK acid + STRONG base = basic solution
  4. Salt of WEAK acid + WEAK base = larger K determines pH
- In every case, the stronger of the pair determines how the water solution of the salt will turn out.

### Examples

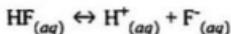
- $\text{KClO}_4$ 
  - This is the salt of  $\text{KOH}$  (STRONG BASE) and  $\text{HClO}_4$  (STRONG ACID).
  - Therefore the solution is neutral.
  - The process is simple: the first ion - the cation - comes from the original base; if it is from Group I or II, the base was strong; the base cation is then replaced with enough hydrogen ions to give the same positive charge; the resulting acid formula is tested with the rules to see if it was strong or weak.
- $\text{Mg}(\text{NO}_2)_2$ 
  - This is the salt of  $\text{Mg}(\text{OH})_2$  (STRONG BASE) and  $\text{HNO}_2$  (WEAK ACID).
  - The solution will be basic.
- $\text{AlCl}_3$ 
  - This is the salt of  $\text{Al}(\text{OH})_3$  (WEAK BASE) and  $\text{HCl}$  (STRONG ACID).
  - The solution will be acidic.
- $\text{NaCl}$ 
  - This is the salt of  $\text{NaOH}$  (STRONG BASE) and  $\text{HCl}$  (STRONG ACID).
  - The solution will be neutral.
- $\text{NaC}_2\text{H}_3\text{O}_2$

- This is the salt of NaOH (STRONG BASE) and  $\text{HC}_2\text{H}_3\text{O}_2$  (WEAK ACID).
- The solution will be basic.

### Common Ion Influence on Acidity

The common ion effect is the shift in equilibrium that occurs when an ion is added that is already in the equation.

Consider the reaction:



- If extra  $\text{F}^-$  is added by the addition of  $\text{NaF}_{(aq)}$  the equilibrium will shift away from the  $\text{F}^-$ .
- In order to do this the  $\text{H}^+$  will be used up thus resulting in a decrease in the  $[\text{H}^+]$ .

Calculations involving  $K_a$ ,  $K_b$  and the common ions are similar to before, but now we have to take into account the common ion concentration.

#### Video

- Sample exercise 15.1; p. 709.
- Study Guide 15.1; p. 310.

#### **Practice Questions:**

**Hydrolysis: Text: p. 703: #'s 103, 105, 107, 109 & 111**  
**Common Ion Effect: Study Guide: p. 333: #'s 1-5**

•



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### *Curriculum Outcomes*

1. To relate molecular complexity to entropy.
2. To calculate entropy for chemical reactions.



## Section 2

### Lesson 3: Entropy Changes and Chemical Reactions

#### REFERENCE

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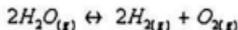
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• Text Sections 16.5; p. 791

• Study Guide Section 16.5; p. 344

The Second Law of Thermodynamics tells us that a process will be spontaneous if the entropy of the universe increases. We can relate this to chemical reactions. If a reaction proceeds to produce fewer molecules then the system entropy has decreased (become more ordered).

Fewer molecules leads to more order.



In this reaction:

- 2 molecules of water is more ordered than 3 molecules of gas on the right.
- Therefore the positional entropy for the forward reaction is positive ( $+\Delta S_{\text{sys}}$ ).

Don't forget that for reactions involving solid, liquids and gases:

$$S_{\text{solid}} < S_{\text{liquid}} \lll S_{\text{gas}}$$

- Sample exercise: 16.6; p. 792.
- Study Guide 16.5 A; p. 346.

#### Third Law of Thermodynamics

The Third Law of Thermodynamics states that the entropy of a *pure* crystal at 0 K is *zero*.

As temperature decreases, molecules slow down and become more ordered. (eg. freezing water) If we cool them down enough, theoretically they will *stop* moving. This theoretical

temperature is zero kelvin. We have seen this before with Charles' Law of gases. This is very convenient, because now we have a reference point to compare all other substances. The values for these *standard enthalpies*,  $\Delta S^{\circ}$ , can be found in appendix 4 of your Text.

- See Text: p. A21.

Calculating the standard enthalpy for a reaction is very much the same as for Hess's law.

$$\Delta S^{\circ}_{\text{reaction}} = \sum n_p \Delta S^{\circ}_{\text{products}} - \sum n_r \Delta S^{\circ}_{\text{reactants}}$$

You have seen this before and it works the same way!

- Sample exercise 16.7 and 16.8; p. 794
- Study guide 16.5 B; p. 346.

**Practice Questions:** p. 814: #'s 33, 35, 37, 39, 41 & 43



*Curriculum Outcomes*

1. To describe how standard reduction potentials are assigned in terms of the standard hydrogen electrode.
2. To demonstrate the combination of half-reactions to form the cell reaction.
3. To characterize a galvanic cell.



## Section 1

### Lesson 2: Reduction Potentials and Half Cells

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- Text Section 17.2; pp. 824 - 829
- Study Guide Section 17.2; p. 359

#### How Much Energy Can We Get From a Galvanic Cell?

We need an easy way to be able to predict how much electrical energy we will get from any particular cell we put together. This can be easily done by comparing each half cell to a known standard.

This standard must be defined by the community of scientists. It's much like the aspect of sea level. We have conveniently assigned sea level to be zero feet (meters). All other altitudes are compared to sea level. We could have just as easily measured from the centre of the earth! In any case we need a zero reference point.

#### **The Standard Hydrogen Electrode**

In electrochemistry, the standard electrode (the electrode that we compare all others to) is the standard hydrogen electrode (SHE). This is simply a half cell in which an inert (unreactive) platinum electrode is in contact with 1 M  $H^+$  and hydrogen gas is bubbled over it at 1 atm. This half cell has been assigned a zero voltage.



When hooked up to any other half cell, the voltage reading is then assigned to that half cell.

- See Text: Figure 17.5; p. 825

Therefore, the SHE is the sea level of electrochemistry! (Ha! Ha! Ha! Ha!)

#### **Standard Electrode Potentials**

Electrochemists then went to work and measured the  $E^\circ$  for many common half cells. The standard conditions for the half cells are defined to be:

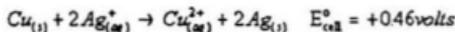
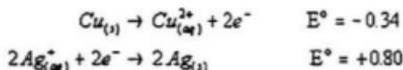
- 25°C,
- 1 atm,
- The electrode (M) must be immersed in 1 mol/L solution of ( $M^{n+}$ ).

• See Text: Table 17.1; p.827.

! Note that the table on p. 827 of the text is a table of standard *reduction* potentials. Therefore, if you need an  $E^\circ$  value for an oxidation equation the sign of the value for  $E^\circ$  must be reversed.

What is the standard potential difference for the cell in the last lesson?

It is simply, the difference between the  $E^\circ$  of the two equations:



$E^\circ$  is an intensive property. That is, it does not depend on amounts, therefore *balancing equations does not affect the magnitude of  $E^\circ$* .

Predicting if a combination of half-cells will spontaneously produce a voltage is easily achieved. Since every half cell is compared to SHE,

- The more positive reduction potential will be the reduction half cell (cathode) and the less positive will be oxidation half cell (anode).
- If the  $E^\circ_{cell}$  is positive the reaction will proceed spontaneously (more on this later)

• Sample exercises 17.1 and 17.2 p. 828

• Study Guide example 17.2 A, B, C, and E p. 360

**Practice Questions: p. 863 #'s 27, 29, 33 & 35**



**Appendix D: Laboratory Activities.**

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● Unit 2, Topic 1, Section 1, Lessons 1 & 2




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## Lab 4: Determination of the Ideal Gas Constant

---

### PURPOSE

1. To prepare hydrogen gas and qualitatively test for its presence.
2. To determine the value of the ideal gas constant R.
3. To apply the ideas of partial pressures, vapor pressure and the ideal gas law.

### INTRODUCTION

In Part I of this experiment we are trying to detect the presence of hydrogen gas. Hydrogen gas is colorless and odorless, but is extremely combustible.

! Great care should be taken when using the 1 M hydrochloric acid.

Part II of this experiment will apply the ideal gas law in an effort to calculate the value of R, the ideal gas constant. In order to do this we need to find; P, V, T, and n.

Finding the number of moles of gas, n, is easy. We will be using a known amount of magnesium and reacting it with excess hydrochloric acid. We can use stoichiometry to find the number of moles of hydrogen gas produced.

The pressure of the gas can be found using Dalton's law of partial pressures.

• See Text: Section 5.5.

Since the hydrogen will be collected over water at a specific temperature we can use the following equation:

$$P_{\text{total}} = P_{\text{H}_2} + P_{\text{water}}$$

Hence:

$$P_{\text{H}_2} = P_{\text{total}} - P_{\text{water}}$$

The value of  $P_{\text{water}}$  can be found using [Table 4.1](#)

Due to the gas being trapped by the water in the burette,  $P_{\text{total}}$  does not equal  $P_{\text{atm}}$ .

Therefore, we must take into account the difference in water level inside the burette and outside in the 600 mL beaker. To do this simply measure the height of the difference (in milliliters) in the water level inside the column and outside in the beaker. The density of water at 25 °C is 1.00 g/mL, which makes it easy to convert the mmHg. We simply divide by 13.5 (the density of Hg) and then convert from mmHg to kPa.

- See the conversion factor in the Text

Therefore to get an accurate pressure on the  $\text{H}_{2(g)}$ :

$$P_{\text{H}_2} = P_{\text{atm}} - P_{\text{level difference}} - P_{\text{water}}$$

$P_{\text{atm}}$  can be found using a barometer or by checking out your local weather on the internet at this link. (Click on it!)

[http://www.stemnet.nf.ca/Services/hourly\\_obs.html](http://www.stemnet.nf.ca/Services/hourly_obs.html)

Record the barometric pressure of the geographic area closest to you in **Table 4.2**

### SAFETY

- Be careful with hydrochloric acid.
- Always wear goggles.
- It would be a good idea to have a jug of sodium bicarbonate handy to neutralize any spills.

### MATERIALS

#### Part I

- Mossy zinc (pea size sample)
- 3 mL of 1M hydrochloric acid ( $\text{HCl}_{(aq)}$ )
- Small test tube
- Wooden splint
- Test tube holder

#### Part II

- Magnesium ribbon (about 5 cm)
- Bare copper wire (25 cm)
- 100.0 mL gas collecting burette
- 50.00 mL of 1M hydrochloric acid
- One hole rubber stopper (size 00) to fit burette

- Ring stand
- Burette clamp
- 600 mL beaker



## PROCEDURE

### Part I

1. Place a small sample of mossy zinc in a test tube.
2. Add about 3 mL of 1 M hydrochloric acid. (Care!)
3. Lightly cap the test tube with a rubber stopper or cork.
4. Wait about 25 seconds then ignite the wooden splint and insert into the mouth of the test tube and quickly remove cap.
5. If no popping sound was heard recap and try again.

Answer questions #1 and #2 on the lab sheet.

### Part II

Record all data in Table 4.2.

1. Obtain a piece of magnesium ribbon. (About 5 cm). Record its mass. (Do not exceed 0.06 g)
2. Take 25 cm of bare copper wire and make a cage to hold the magnesium. Make sure about 5 cm remains as a handle. Place the magnesium inside the cage.
3. Clean and rinse a 100 mL gas burette.
4. Place about 50 mL of 1M hydrochloric acid in the burette. Then fill the burette with water, be careful not to mix the solution.

 Video: Filling the burette

 Video: Topping the burette off with water

5. Insert the caged magnesium in the burette (Be careful not to lose it). Keep the cage in place using a one hole rubber stopper. The stopper must have a hole in it to allow the solution to escape by the production of hydrogen gas. Make sure there is no air in the burette.
6. Quickly invert the burette into 600 mL beaker half full of water. Keep it in place using a ring stand and burette clamp.

 Video: Inverting the burette.

7. Wait about five minutes or until the reaction stops.
8. Record the temperature of the water in the beaker.
9. Tap the sides of the burette to free any trapped hydrogen bubbles.
10. Record the gas volume in the data table
11. Measure and record the water level difference.

 Video: Measuring the water level difference

12. Raise the burette to allow all the acid to escape.
13. Flush the remaining solution down the drain and rinse burette.

## QUESTIONS AND CALCULATIONS

### Part I

1. Describe a chemical test for the presence of hydrogen gas.
2. Write a balanced chemical equation for the reaction of zinc with hydrochloric acid.

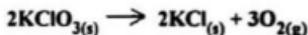
### Part II

1. Write a balanced chemical equation for the reaction of Magnesium with hydrochloric acid.
2. Calculate the number of moles of magnesium used.
3. Using stoichiometry, calculate the number of moles of hydrogen gas produced.
4. Convert temperature from Celsius to Kelvin.
5. Calculate the pressure due to the level difference of the water inside and out of the burette.
6. Calculate the pressure of the hydrogen gas; (i.e.  $P_H = P_{\text{atm}} - P_{\text{level difference}} - P_{\text{water}}$ )
7. Using the ideal gas law and your data, calculate the experimental value of R.
8. Given that the accepted (theoretical) value of  $R = 8.314 \text{ (L kPa)/(mol K)}$ , calculate the

percent error for your experiment.

$$\% \text{error} = (\text{accepted} - \text{experimental}) / \text{accepted} \times 100$$

9. \* A sample of  $\text{KClO}_{3(s)}$  was decomposed by the following reaction:



The oxygen produced was collected by displacement of water at  $22^\circ\text{C}$  at a total pressure of 754 mmHg. The volume of the gas collected was 0.650 L. The vapor pressure due to water at  $22^\circ\text{C}$  is 21 mmHg.

- Calculate the partial pressure of  $\text{O}_{2(g)}$  collected.
- Calculate the mass of  $\text{KClO}_3$  decomposed.

**Table 4.1: Vapor Pressure of Water**

<b>Temperature (°C)</b>	<b>Vapor Pressure of Water (kPa)</b>
13	1.49
14	1.60
15	1.71
16	1.81
17	1.93
18	2.07
19	2.20
20	2.33
21	2.49
22	2.64
23	2.81
24	2.99
25	3.17

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**Table 4.2: Determination of the Ideal gas constant, R**

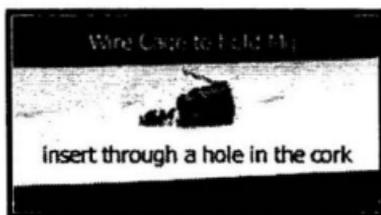
Mass of magnesium (g)	
Temperature of trapped gas ( °C) ( <i>Water temp</i> )	
Vapor pressure of water at ( ___ °C) in kPa ( <i>from table 4.1</i> )	
Volume of H <sub>2</sub> in tube :	
Water level difference (mm water)	
Barometric pressure (kPa) (at time lab was done)	

Name: \_\_\_\_\_

School: \_\_\_\_\_

**Table 4.2: Determination of the Ideal gas constant, R**

Mass of magnesium (g)	
Temperature of trapped gas ( °C) ( <i>Water temp</i> )	
Vapor pressure of water at ( ___ °C) in kPa ( <i>from table 4.1</i> )	
Volume of H <sub>2</sub> in tube :	
Water level difference (mm water)	
Barometric pressure (kPa) (at time lab was done)	



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● Unit 2, Topic 3, Section 3, Lesson 2



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## Lab 5: Colligative Properties: Freezing Point Depression and Molar Mass

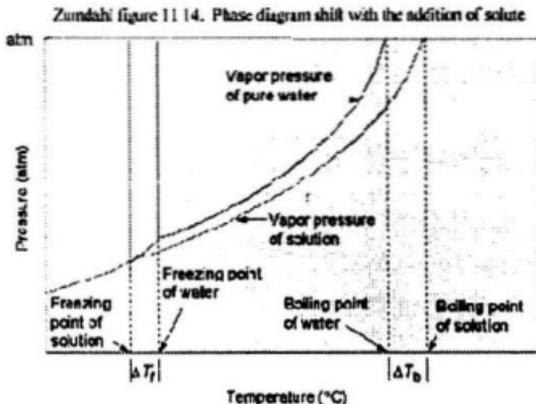
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### PURPOSE

1. To generate a cooling curve for a pure substance.
2. To generate a cooling curve for a solution.
3. To determine the molar mass of sulfur using the colligative property of freezing point depression.

### **INTRODUCTION**

When a solute is dissolved in a solvent, the properties of the solvent are changed by the presence of the solute. The amount of the change is generally proportional to the amount of the solute added. Some properties of the solvent are changed only by the number of solute particles present, without regards to the nature of the solute. Such properties are called colligative properties of the solution. Colligative properties include changes in; vapor pressure, boiling point, freezing point, and osmotic pressure. In such situations, the solute interacts with the solvent and lowers the vapor pressure of the solvent. As indicated in figure 11.14 from Zumdahl lowering of the vapor pressure raises the boiling point and lowers the freezing point. We use such properties in our car engines. By having a solution of water and ethylene glycol (antifreeze) we can lower the freezing point and elevate the boiling point of the liquids in the engine. A win-win situation!



- For sample calculations, see Text; exercises 11.8 and 11.10.

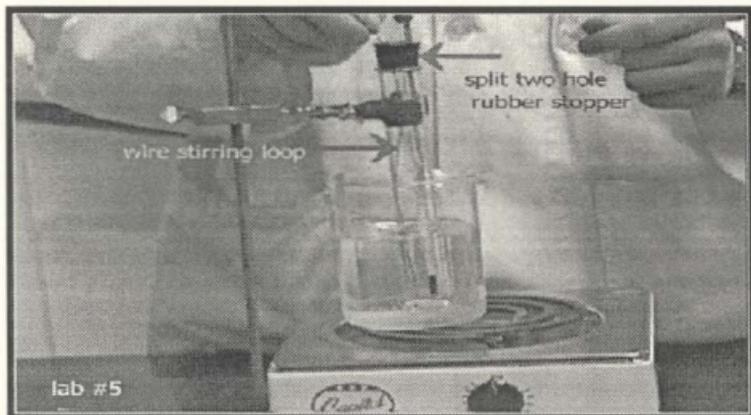
## SAFETY

- Wear safety goggles at all times.
- Naphthalene (commercial name -- moth balls) is toxic. Try to avoid contact with the skin and avoid breathing the vapor.
- Naphthalene vapor is flammable, do not use in the presence of open flame. (ie: NO BUNSEN BURNERS!)
- Work in a well ventilated room.
- Use glycerin or other lubricant when inserting thermometer in the rubber stopper.
- When inserting the thermometer in the rubber stopper, protect your hands with heavy gloves or a towel.

## MATERIALS

- Large test tube
- Two-hole rubber stopper (to fit test tube)
- Thermometer
- Copper wire (bent to be used as a stirrer)
- Ring stand
- Test tube clamp
- Ring clamp
- Wire gauze

- Hot plate
- 600 mL beaker
- 15 g naphthalene  $C_{10}H_8(s)$  ("moth balls")
- 1.5 g sulfur
- Large bottle (miracle whip or mason jar)



## PROCEDURE

Data gathered must be recorded in the given tables. Do not forget to sign your name at the top of each page.

### Part I

Record all data in Table 5.1.

1. Weigh and record the mass of a large, clean dry test tube.
2. Add about 15 g of naphthalene. Reweigh and record.
3. Make a loop in one end of the copper wire. This will be your stirrer.
4. Carefully insert a thermometer into a two hole rubber stopper that has been slit. You may want to use some glycerin or other lubricant. It may be better to use a vernier temperature probe and MPLI if it is available.

 **Video:** Preparing the rubber stopper and lubricating the thermometer

5. Insert the stirrer in the other hole.
6. Fill a 600 mL beaker with water and heat it to about  $85^{\circ}\text{C}$ . (Do not use a bunsen burner to heat this, naphthalene is flammable)

7. Clamp the test tube in the water bath as shown in the figure above.
8. When most of the naphthalene has melted, lightly insert the rubber stopper-thermometer-stirrer apparatus in the test tube.
9. Make sure that the thermometer is not touching the sides or bottom of the test tube.
10. When all of the naphthalene has melted, remove the test from the water bath.
11. Record the temperature of the naphthalene every thirty (30 s) seconds while stirring, until all the naphthalene has solidified. (Table 5.1 b)
12. This same apparatus is used in Part II. Do not discard.

### Part II: Cooling Curve for Sulfur-Naphthalene Solution

Record all data in Table 5.2

1. Using plastic weighing boat or vial, weigh out about 1.5 g of sulfur. Record the mass in Table 5.2
2. Return the test tube to the water bath and heat until all the naphthalene has melted.
3. Carefully remove the rubber stopper, be sure not to lose any naphthalene.
4. Carefully add the sulfur to the test tube.
5. Replace the stopper and stir the solution until all the sulfur has dissolved.
6. Remove the test tube from the water bath, wipe dry, and record temperatures every 30 seconds while stirring until all the naphthalene has solidified. (Table 5.2 b)
7. Record the mass of the empty weighing boat.

### QUESTIONS AND CALCULATIONS

1. Plot temperature (Y axis) Vs time (X axis) graphs of part A and part B on the same axis (must be done on graph paper).
2. Did the addition of the sulfur have any effect on the freezing point of pure naphthalene?
3. From the graph determine the  $\Delta T$ .

$$\Delta T = T_{F \text{ solvent}} - T_{F \text{ solution}}$$

4. The  $K_b$  for naphthalene is  $6.9^\circ\text{C kg/mol}$ . Calculate the molality of the sulfur.

$$\Delta T = K_b m_{\text{solute}}$$

5. Molality is given in as moles of solute/ kg of solvent. Calculate the moles of sulfur.
6. Calculate the molar mass of sulfur.
7. The molecular formula of sulfur is  $S_8$ . Calculate the % error and discuss any discrepancies (differences) .

$$\% \text{error} = (\text{accepted} - \text{experimental}) / \text{accepted} ) * 100\%$$

8. \* An unknown compound contains only three elements C, H, and O. A pure sample of the compound is analyzed and found to be 65.60% C and 9.44% H by mass.
- Determine the empirical formula of the compound.
  - A solution of 1.570g of the compound in 16.08g of camphor is observed to freeze at a temperature 15.2°C below the normal freezing point of pure camphor. Determine the molar mass and apparent molecular formula of the compound. (The molal freezing-point depression constant,  $K_f$ , for camphor is 40.0 kg K mol<sup>-1</sup>)

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● Unit 2, Topic 3, Section 3, Lesson 2



Name: \_\_\_\_\_

School: \_\_\_\_\_

**Table 5.1: Mass Data for Part I: Pure Naphthalene**

1. Mass of test tube + naphthalene (g)	
2. Mass of test tube (empty) (g)	
3. Mass of naphthalene (g) ( #1 - #2)	

**Table 5.1 (b) : Cooling of Pure Napthalene**

Time (s)	Temp (C)		Time (s)	Temp (C)
0			330	
30			360	
60			390	
90			420	
120			450	
150			480	
180			510	
210			540	
240			570	
270			600	
300			more if needed	

Name: \_\_\_\_\_

School: \_\_\_\_\_

**Table 5.2: Mass Data for Part I: Sulfur-Naphthalene Solution**

1. Mass of test tube + sulfur (g)	
2. Mass of test tube (empty) (g)	
3. Mass of sulfur (g) ( #1 - #2)	

**Table 5.2 (b) : Cooling of Sulfur-Naphthalene Solution**

Time (s)	Temp (C)		Time (s)	Temp (C)
0			330	
30			360	
60			390	
90			420	
120			450	
150			480	
180			510	
210			540	
240			570	
270			600	
300			more if needed	

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● Unit 3, Topic 2, Section 1, Lesson 2 & 3



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## Lab 6: Acid-Base Titration

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### PURPOSE

1. To practice the techniques involved in an acid base titration.
2. To perform stoichiometry calculations on a neutralization reaction.

### INTRODUCTION

Titration involves measuring the exact volume of a solution of known concentration that is needed to completely react with a measured volume of an unknown concentration. In this lab, we wish to find the concentration of a sample of sodium hydroxide using a standard sample of hydrochloric acid. This reaction is a neutralization reaction. Since we are dealing with a monoprotic acid and base the stoichiometric ratio is one to one. Therefore, one mole of standard HCl neutralizes one mole of NaOH. However, the problem here is to know when the neutralization point (endpoint) is reached. To find this equivalence point, we make use of *indicators*. An indicator is a chemical that is added at the beginning of the titration and changes color when the equivalence point is reached. For this acid-base titration, we will use the indicator phenolphthalein. Phenolphthalein is pink in color under basic conditions and is colorless in acidic conditions. The transition in color is in the pH range of about 8.2 to 10.

### SAFETY

- Safety goggles must be worn.
- Never pipette by mouth; always use a pipette bulb!

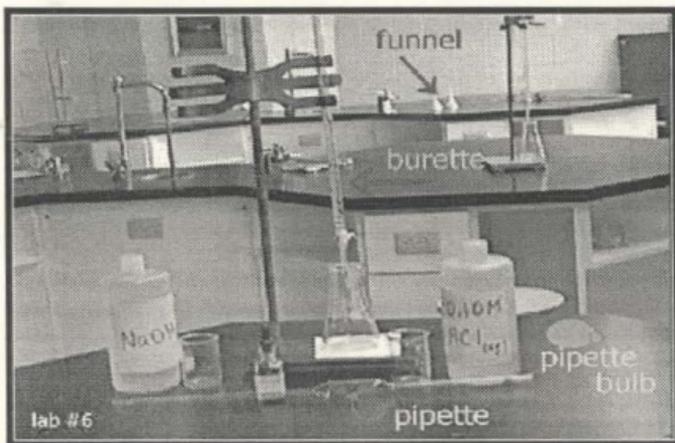
 Video: Pipetting technique

- Avoid contact of hydrochloric acid with skin. Neutralize spills using some sodium bicarbonate solution.

### MATERIALS

- 250 mL Erlenmeyer flask (conical)
- 50.00 mL burette
- 25.00 mL pipette
- Pipette bulb
- Ring stand
- Burette clamp
- Phenolphthalein indicator

- 300 mL of 0.10 mol/ L sodium hydroxide
- 100 mL of 0.10 mol/ L hydrochloric acid.
- 1 g benzoic acid



### PROCEDURE

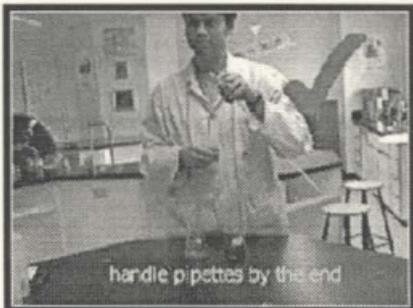
Record all results in the table provided.

1. Wash and rinse a 250 mL Erlenmeyer flask, rinse with distilled or deionized water. Rinse the flask with several small amounts of sodium hydroxide. Then collect about 200 mL of the 0.10 mol/ L sodium hydroxide. Be sure to label your flask!
2. Wash and rinse a 50.00 mL burette and a 25.00 mL pipette. Rinse both with deionized or distilled water.
3. Rinse the burette (the long one) with the sodium hydroxide. Then fill it with the sodium hydroxide. Place it in the burette clamp.

 Video: Filling the burette

4. In a small clean dry beaker, collect about 100 mL of the 0.10 mol/ L hydrochloric acid. Label the beaker.

Review the Video on how to pipette correctly. The figures below illustrate the right and wrong way to handle the pipette:



- Rinse your pipette with several small portions of the hydrochloric acid. Throw your rinse solution in a waste beaker or down the drain. Do not put it back in your beaker!
- Using your pipette and pipette bulb, pipette 25.00 mL of hydrochloric acid into a second clean Erlenmeyer flask. Wait for all the solution to drain but do not blow out the small amount that remains in the tip.



- Add a couple of drops of phenolphthalein indicator.
- Record the initial volume in the burette. Remember to take the readings from the bottom of the meniscus.
- Slowly begin adding sodium hydroxide from the burette to the contents of the Erlenmeyer flask until a pink color faintly appears then disappears. You are very near the neutralization point. Add sodium hydroxide until a very faint pink color remains. At this point record the volume of the burette.
- Discard the contents of the flask in the drain, rinse and repeat Steps 7 to 10 Don't forget to refill your burette with sodium hydroxide. Continue until you can get two good titrations that are within 0.10 mL of the same volume.

## CALCULATIONS

1. Write a balanced chemical equation for this reaction.
2. Write a total ionic equation for this reaction.
3. Write a net ionic equation for this reaction.
4. Calculate the number of moles of hydrochloric acid used in this reaction.
5. Using stoichiometry and your balanced equation in #1, how many moles of sodium hydroxide reacted?
6. Calculate the concentration of the sodium hydroxide.

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● Unit 3, Topic 2, Section 1, Lesson 2 & 3



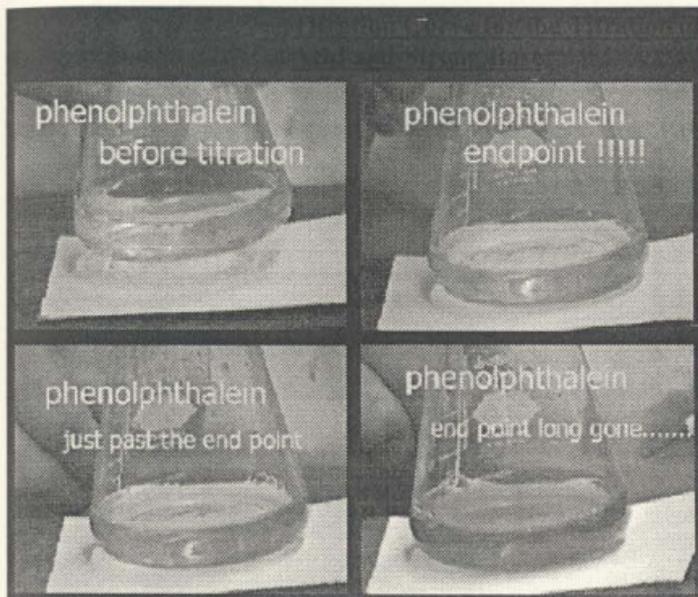
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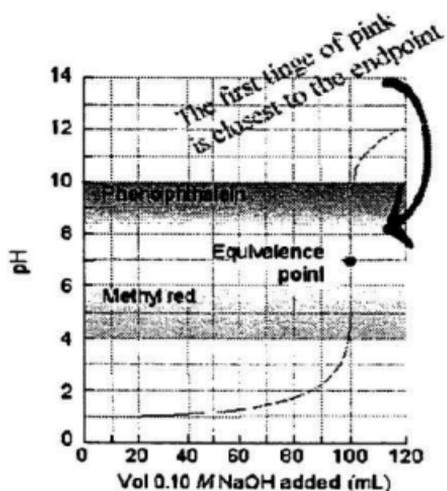
**Table 6.1: Titration of Sodium Hydroxide with 25.00 mL of Standard 0.10 mol/ L Hydrochloric Acid**

<b>Indicator: Phenolphthalein colorless in acid - pink in base.</b>			
<b>Burette reading (mL)</b>	<b>Trial #1</b>	<b>Trial #2</b>	<b>Trial #3</b>
<b>Final</b>			
<b>Initial</b>			
<b>Volume of NaOH used</b>			
<b>Average of two closest trials:</b>			

file:///D:/apchemistry/labs/lab06/titration\_with\_phenolphthalein.htm



## Titration Curve for the Titration of a Strong Acid and Strong Base



Zumdahl - Chemistry 4th ed - Figure 15.9

● Unit 3, Topic 3, Sections 1 & 2



## Lab 8: Chemical Kinetics: The Rate Laws

### PURPOSE

1. To observe the effects of concentration on reaction rate.
2. To observe the effects of temperature on reaction rate.
3. To determine the rate order of a reaction use graphical analysis.
4. To practice graphing experimental data.
5. To calculate the activation energy of a reaction.

### INTRODUCTION

In this lab activity, you will react a solution of sodium thiosulphate,  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ , with hydrochloric acid  $\text{HCl}(\text{aq})$  to produce a milk-white colloidal suspension of sulfur. The equation for the reaction is:



In Part I of this experiment you will be studying the effects of concentration on reaction rate. The concentration of the  $\text{Na}_2\text{S}_2\text{O}_3$  will be changed while the concentration of the  $\text{HCl}(\text{aq})$  will be held constant. The reaction time for each trial will be measured by examining the production of sulfur,  $\text{S}_8(\text{s})$ . Solid sulfur forms a colloidal suspension, which characteristically blocks out visible light. Therefore we will take timing of how long it takes the precipitate to block out an X marked below the beaker.

The rate of the reaction can be found using the following equation:

$$\text{Rate} = \frac{\Delta \text{ amount of sulfur}}{\Delta \text{ time}}$$

At a constant temperature the rate law expression with respect to  $\text{S}_2\text{O}_3^{2-}$  can be written.

$$\text{Rate} = k [\text{S}_2\text{O}_3^{2-}]^n$$

The rate constant,  $k$  and the rate order, must be determined by experiment. Finding the value of  $k$  requires that the amount of sulfur produced needs to be known. We will not be

measuring mass, thus not finding  $k$  directly. However we can find the values of  $n$  and  $k$  by graphical analysis. For zero order reactions  $n = 0$ , the graph of  $[S_2O_3^{2-}]$  versus time is a straight line. For first order reactions,  $n = 1$ , a graph of  $\ln [S_2O_3^{2-}]$  Vs time is a straight line. For a second order reaction,  $n = 2$ , a graph of  $1/[S_2O_3^{2-}]$  Vs time is a straight line. The slope of each would indicate the value of  $k$ .

In the second part of this experiment, you will examine the effects of temperature on reaction rate. Here all concentrations are the same, but the temperature will be changed for each trial. The underlying idea is that by increasing temperature reaction rate is increased also. The increased temperature relates to the increased kinetic energy of the molecules, thus resulting in increased number and energy of collisions. In this experiment we will graphically find the activation energy for the above reaction. To do this we need to use the Arrhenius equation.

$$\text{Rate} \propto 1/t$$

$$1/t = Ae^{-E_a/RT}$$

Where:

$t$  = time

$T$  = temp(K)

$R$  = ideal gas constant

$A$  = constant

By taking the natural log of each side we get:

$$\ln(1/t) = (-E_a/R)(1/T) + \ln(A)$$

This is now in the form  $y = mx + b$ , therefore the slope of the graph of  $\ln(1/t)$  Vs:  $1/T$  would be  $-E_a/R$ .

### **SAFETY**

- Safety goggles must be worn at all times.
- Care should be taken not to get hydrochloric acid on your skin. Spills should be neutralized with a solution sodium bicarbonate.

### **MATERIALS**

- 1 150 mL beaker
- 10 mL graduated cylinder
- 200 mL of 0.2 mol/ L sodium thiosulphate
- 50 mL of 2.0 mol/ L hydrochloric acid

- Ice bath
- Thermometer
- Warming source (Bunsen burner or hot plate)
- Stopwatch or wrist watch

## PROCEDURE

### Part I

Record all data in Table 8.1

1. Get a clean 150 mL beaker.
2. Take a piece of white paper and mark an X on it, about the size of the beaker. Make sure you use the same X all the time.

 **Video:** Experimental details

3. Add 50 mL of the  $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$  to the beaker.
4. Record the temperature of the solution.
5. Place the beaker on the X.
6. Get ready to add 5.0 mL of  $\text{HCl}(\text{aq})$ . Begin timing as soon as the solutions are mixed. Swirl the contents.
7. Looking down in the flask, note the time when the X disappears. Record your time. It will be important to be consistent with each trial.
8. Discard the solution and thoroughly clean and rinse the flask.
9. Repeat the procedure but this time we will be diluting the  $\text{Na}_2\text{S}_2\text{O}_3$  with water as per the following table:

Trial Number	1	2	3	4	5
0.20 mol/L $\text{Na}_2\text{S}_2\text{O}_3$ (mL)	50	40	30	20	10
Water (mL)	0	10	20	30	40
2M $\text{HCl}(\text{aq})$ (mL)	5	5	5	5	5
Total Volume (mL)	55	55	55	55	55

**Part II: The Effect of Temperature on Reaction Rate - Calculation of  $E_a$ .**

Record all data in Table 8.2

1. Get a clean 150 mL beaker.
2. Obtain 10 mL of  $\text{Na}_2\text{S}_2\text{O}_3$ . Dilute to 50 mL with water.
3. Get a graduated cylinder and obtain 5.0 mL of HCl.
4. Do not add the acid yet.
5. Cool the  $\text{Na}_2\text{S}_2\text{O}_3$  in the beaker and the acid in the cylinder down to about  $5^\circ\text{C}$  in an ice bath.
6. When the temperature gets down reasonably close, record the temperature.
7. Add the acid to the  $\text{Na}_2\text{S}_2\text{O}_3$ . Swirl and record the time.
8. Record the time it takes for the X to disappear.
9. Repeat procedure for the other temperature.

**CALCULATIONS****Part I**

1. Calculate the concentration of  $\text{S}_2\text{O}_3^{2-}$  (aq) for each trial.
2. Plot a graph of  $[\text{S}_2\text{O}_3^{2-}]$  (y-axis) versus time (t) (x-axis). What is the significance of this graph?
3. Plot a graph of  $\ln[\text{S}_2\text{O}_3^{2-}]$  (y-axis) versus time (t) (x-axis). What is the significance of this graph?
4. Plot a graph of  $1/[\text{S}_2\text{O}_3^{2-}]$  (y-axis) versus time(t). What is the significance of this graph (\* this graph should be linear).
5. What is the order of this reaction?
6. What is the rate constant for this reaction?
7. What is the rate law for this reaction?
8. Why should the temperature and concentration of HCl remain constant?

**Part II**

1. Plot a graph of  $\ln(1/t)$  Vs:  $1/T$
2. Calculate the slope of the graph.
3. Calculate the  $E_a$  of the reaction. Slope =  $-E_a/R$ , where R is the ideal gas constant.

**Discussion of possible sources of errors in Part I and Part II.**

- Unit 3, Topic 3, Sections 1 & 2



Name: \_\_\_\_\_

School: \_\_\_\_\_

**Table 8.1: Effects of Concentration on Reaction Rate**

All temperatures are in °C

Trial Number	$[\text{S}_2\text{O}_3^{2-}]$	Reaction time (t) (seconds)	Reaction rate $1/t \text{ (s}^{-1}\text{)}$	$\ln [\text{S}_2\text{O}_3^{2-}]$	$1/[\text{S}_2\text{O}_3^{2-}]$
1	0.18 mol/L				
2					
3					
4					
5					

Name: \_\_\_\_\_

School: \_\_\_\_\_

**Table 8.2: The Effects of Temperature on Reaction Rate**

Temp °C	Actual Temp°C	Temp in Kelvin (K)	(1/T) K <sup>-1</sup>	Time (seconds)	1/t s <sup>-1</sup>	ln (1/t)
5°C						
10°C						
20°C						
30°C						
40°C						
50°C						
60°C						

**Appendix E: Assignments and Sample Solutions.**



## Chemistry 4222

### Assignment 1

(Unit 1 - Topics 1 - 2)

Due: October 9th, 1998

{20 marks}

#### Marks

- {1} 1. Calculate the percent composition for each of the following.
- $\text{CCl}_4$
  - $\text{C}_{18}\text{H}_{12}\text{O}_6$
- {1} 2. A compound of carbon and hydrogen consists of 93.71% C and 6.29% H by mass. The molecular mass of the compound is found to be 128 u. What is its molecular formula?
- {2} 3. A 2.500 g sample of a compound consisting of only lithium, chlorine, and oxygen is heated for a period of time to drive off the oxygen. The remaining residue weighs 1.170 g. This residue is now dissolved in water and treated with silver nitrate. All the chloride precipitates as  $\text{AgCl}$ , which weighs 3.963 g. Calculate the mass of lithium, chlorine, and oxygen atoms in the 2.500 g sample of the compound and find the empirical formula of the compound.
- {1} 4. Write a net ionic equation for the reaction of Iron (III) nitrate with sodium hydroxide
- {2} 5. Balance the following redox equation in acidic conditions:
- $$\text{Zn}_{(s)} + \text{H}^+ + \text{NO}_3^- \longrightarrow \text{Zn}^{2+} + \text{NH}_4^+ + \text{H}_2\text{O}$$
- {2} 6. Balance the following redox equation in basic conditions.
- $$\text{MnO}_{2(s)} + \text{BiO}_3^- \longrightarrow \text{MnO}_4^- + \text{Bi}^{3+}$$
7. In the hall process for the isolation of aluminum from its oxide the reaction represented below occurs.
- $$\text{Al}_2\text{O}_{3(s)} + \text{C}_{(s)} \longrightarrow \text{Al}_{(s)} + \text{CO}_{2(g)}$$
- {1} a. If 10.0 mol of C and 8.00 mol of  $\text{Al}_2\text{O}_3$  are combined, what is the theoretical yield in grams of Al?
- {1} b. If the experiment above was performed and only 4.00 grams of Al were produced, what is the percent yield of Al?
- {1} 8. Answer the following questions:

- a. The ionization energy of gold is 890.1 kJ/mol. Is light with a wavelength of 225 nm capable of ionizing a gold atom?
- {1} b. An excited hydrogen atom emits light with a frequency of  $1.141 \times 10^{14}$  Hz to reach the energy level for which  $n = 4$ . In what principal quantum level did the electron begin?
- {1.5} 9. Answer the following questions:

a. The ionization energies in kcal for Mg and Ca are:

	Mg	Ca
1st	176	141
2 <sup>nd</sup>	346	247
3rd	1847	?

- i. Indicate the reasons for the relatively high 3rd ionization energy for magnesium.
- ii. Indicate the reasons for the differences in 1st ionization energies for Mg and Ca.
- iii. Predict the 3rd ionization energy for calcium.
- {1.5} b. Explain in terms of electron configuration, why the decrease in atomic radius from Ca to Ga is greater than that from Mg to Al?
- {2} 10. Answer the following questions:

a. Which of the following sets of quantum numbers are possible for an electron in an atom and which are impossible. For those impossible indicate why?

- i.  $n = 1, l = 0, m_l = 1, m_s = +\frac{1}{2}$
- ii.  $n = 4, l = 2, m_l = 0, m_s = -\frac{1}{2}$
- iii.  $n = 3, l = 3, m_l = -2, m_s = -\frac{1}{2}$
- iv.  $n = 4, l = 0, m_l = 0, m_s = 0$
- v.  $n = 2, l = 1, m_l = -1, m_s = +\frac{1}{2}$

- {2} b. Three species are iso-electronic in that they all contain 36 electrons. One is neutral atom, one is a cation and one is an anion.
- i. Identify the three species using symbols and charge
- ii. Write the ground state configuration for each species.
- iii. Which would you predict to have the largest radius. Explain.

## Chemistry 4222

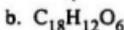
### Solutions to Assignment #1

#### (Unit 1 - Topics 1 - 2)

{20 marks}

Marks

{1} 1. Calculate the percent composition for each of the following.



(b)

$$\text{MM}_{\text{C}_{18}\text{H}_{12}\text{O}_6} = 324.26 \text{ g/mol}$$

(a)

$$\text{MM}_{\text{CCl}_4} = 153.81 \text{ g/mol}$$

$$\% \text{C} = \frac{18 \times 12.01}{324.26} \times 100\% = 66.7\%$$

$$\% \text{C} = \frac{1 \times 12.01}{153.81} \times 100\% = 7.808\% \quad \% \text{H} = \frac{12 \times 1.01}{324.26} \times 100\% = 3.73\%$$

$$\% \text{Cl} = \frac{4 \times 35.45}{153.81} \times 100\% = 92.19\% \quad \% \text{O} = \frac{6 \times 16.00}{324.26} \times 100\% = 29.60\%$$

{1} 2. A compound of carbon and hydrogen consists of 93.71% C and 6.29% H by mass. The molar mass of the compound is found to be 128 u. What is its molecular formula?

#2

Determine the mass of each element for 100g

$$M_C = 93.71\% \times 100\text{g} = 93.71\text{g}$$

$$M_H = 6.29\% \times 100\text{g} = 6.29\text{g}$$

Find the number of moles of each.

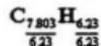
$$n_C = \frac{m}{M} = \frac{93.71}{12.01} = 7.803\text{mol C}$$

$$n_H = \frac{m}{M} = \frac{6.29}{1.01} = 6.23\text{mol H}$$

Establish ratios:



Divide by the smallest value:

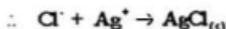
The molar mass of  $C_5H_4 = 64.0\text{g/mol}$ ∴ the empirical formula must be  $C_{10}H_8$ 

- {2} 3. A 2.500 g sample of a compound consisting of only lithium, chlorine, and oxygen is heated for a period of time to drive off the oxygen. The remaining residue weighs 1.170 g. This residue is now dissolved in water and treated with silver nitrate. All the chloride precipitates as  $AgCl$  which weighs 3.963 g. Calculate the mass of lithium, chlorine, and oxygen atoms in the 2.500 g sample of the compound and find the empirical formula of the compound.

#3

$$m_0 = 2.500 - 1.170 = 1.330 \text{ g of O}$$

the residue contains only Li and Cl, all the Cl reacts with Ag.



$$m_{\text{AgCl}} = 3.963 \text{ g}$$

$$n_{\text{AgCl}} = \frac{m}{M} = \frac{3.963}{143.32} = 0.02765 \text{ mol AgCl}$$

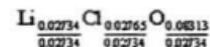
1:1 mole ratio

$$\therefore m_{\text{Cl}} = nM = 0.02765 \times 35.45 = 0.9802 \text{ g of Cl}$$

$$\therefore m_{\text{Li}} = \text{total} - m_{\text{O}} - m_{\text{Cl}} = 2.500 - 1.170 - 0.9802 = 0.1898$$

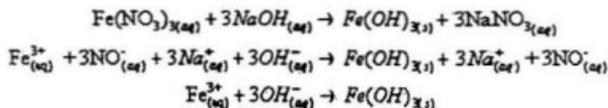
Find the moles of each to get the empirical formula:

$$n_{\text{Li}} = \frac{0.1898}{6.94} = 0.02734 \text{ mol} \quad n_{\text{O}} = \frac{1.330}{16.00} = 0.08313 \text{ mol} \quad n_{\text{Cl}} = 0.02765 \text{ mol}$$

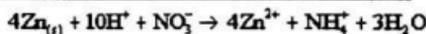
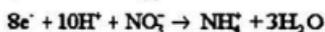
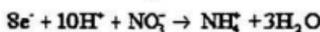
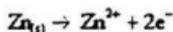
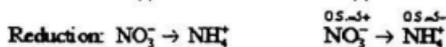
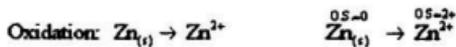
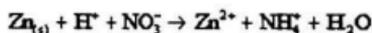
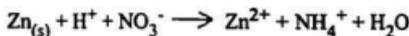


- {1} 4. Write a net ionic equation for the reaction of Iron (III) nitrate with sodium hydroxide

Iron(III) Nitrate + Sodium Hydroxide  $\rightarrow$  Iron (III) hydroxide + sodium nitrate



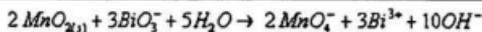
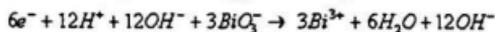
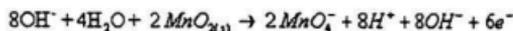
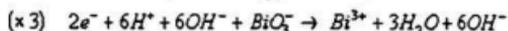
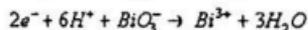
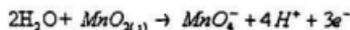
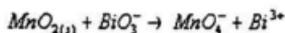
- {2} 5. Balance the following redox equation in acidic conditions:



- {2} 6. Balance the following redox equation in basic conditions.



#6



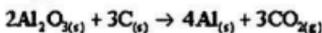
7. In the hall process for the isolation of aluminum from its oxide the reaction represented by occurs.



{1}

- a. If 10.0 mol of C and 8.00 mol of  $\text{Al}_2\text{O}_3$  are combined, what is the theoretical yield in grams of Al?

#7(a)



Find limiting reagent

$$\frac{10.0 \text{ mol}}{3 \text{ C}} = 3.33 \quad \frac{8.00 \text{ mol}}{2\text{Al}_2\text{O}_{3(s)}} = 4.00$$

∴ C is the L.R.

$$\frac{3}{n_{\text{C}}} = \frac{4}{n_{\text{Al}}} \quad \frac{3}{10.0 \text{ mol}} = \frac{4}{n_{\text{Al}}} \quad n_{\text{Al}} = 13.3 \text{ mol}$$

- a.  $m_{\text{Al}} = nM = 13.3 \times 26.98 = 359 \text{ g Al}_{(s)}$  (theoretical yield)

{1}

- b. If the experiment above was performed and only 4.00 grams of Al were produced, what is the percent yield of Al?

7(b)

$$\begin{aligned} \% \text{yield} &= \frac{\text{actual}}{\text{theoretical}} \times 100\% \\ &= \frac{4.00 \text{ g}}{359} \times 100\% \\ &= 1.11\% \end{aligned}$$

{1}

8. Answer the following questions:

- a. The ionization energy of gold is 890.1 kJ/mol. Is light with a wavelength of 225 nm capable of ionizing a gold atom?

8(a)

890.1kJ / mol we need to find the amount of energy required for one atom of gold.

$$E \text{ for 1 atom} = \frac{890\text{kJ}}{1 \text{ mol}} \times \frac{1\text{mol}}{6.022 \times 10^{23} \text{ atoms}} = 1478 \times 10^{-21} \text{kJ (convert to J} \times 1000) = 1.478 \times 10^{-18} \text{ J}$$

$$E = \frac{hc}{\lambda}, \quad \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \text{ Js} \times 3.00 \times 10^8 \text{ m/s}}{1.478 \times 10^{-18} \text{ J}} = 1.344 \times 10^{-7} \text{ m} = 134.4 \text{ nm}$$

**No, it will take light with a wavelength of 134.4 nm or less (shorter is higher energy) to ionize gold. A photon of light with a wavelength of 225 is longer wavelength, and, thus lower energy than 134.4 nm light.**

{1}

- b. An excited hydrogen atom emits light with a frequency of  $1.141 \times 10^{14}$  Hz to reach the energy level for which  $n = 4$ . In what principal quantum level did the electron begin?

8(b)

$$\Delta E = hv = 6.63 \times 10^{-34} \text{ Js} \times 1.141 \times 10^{14} \text{ s}^{-1} = 7.560 \times 10^{-20} \text{ J}$$

$$\Delta E = -7.560 \times 10^{-20} \text{ J since light is emitted.}$$

$$\Delta E = E_4 - E_n.$$

$$-7.560 \times 10^{-20} \text{ J} = -2.178 \times 10^{-18} \text{ J} \left( \frac{1}{4^2} - \frac{1}{n^2} \right)$$

$$3.471 \times 10^{-2} = 6.250 \times 10^{-2} - \frac{1}{n^2}$$

$$\frac{1}{n^2} = 2.779 \times 10^{-2}$$

$$n^2 = 35.98$$

$$n = 6$$

{1.5} 9. Answer the following questions:

- a. The ionization energies in kcal for Mg and Ca are:

	Mg	Ca
1st	176	141
2 <sup>nd</sup>	346	247
3 <sup>rd</sup>	1847	?

- i. Indicate the reasons for the relatively high 3rd ionization energy for magnesium.

**Magnesium is a group II element. Its valence electrons are in the  $3s^2$  orbitals. Removal of the first two electrons is relatively easy, since we have a small amount of shielding from the  $2p^6$  electrons. As the electrons are removed the atomic radius of the Mg ion becomes smaller (due to increased attraction of fewer electrons for the protons). Trying to remove a third electron requires pulling an electron away from a much closer distance from the nucleus, also the third electron is part of the stable  $2p^6$  configuration (noble gas-like configuration).**

- ii. Indicate the reasons for the differences in 1st ionization energies for Mg and Ca.

**Both Mg and Ca are group II elements, thus they have  $3s^2$  and  $4s^2$  valence electrons. The first ionization energy for Ca is smaller than that of Mg primarily due to shielding. Valence electrons of Ca experience much more shielding since they are shielded by an extra orbital of electrons. This inner shielding causes the valence electrons of Ca to be less attracted to the protons of the nucleus.**

- iii. Predict the 3rd ionization energy for calcium.

**The third ionization energy for Ca should be larger than the 2<sup>nd</sup> ionization for the same reasons mentioned in (i) above. However it should be slightly less than that for Mg for reasons of shielding mentioned in (ii) above. To make a prediction, I would say somewhere around 1700 kCal.**

- b. Explain in terms of electron configuration, why the decrease in atomic radius from Ca to Ga is greater than that from Mg to Al?

**The decrease in atomic radius from Ca to Ga is greater than that from Mg to Al is primarily due to the number of electrons involved. Going from Ca (element 20) to Ga (element 31) we proceed from Ca -  $4s^2$  to Ga -  $3d^{10}$ . (10 electrons). Going from Mg (element 12) to Al (element 13) the d-block is not required we go from Mg -  $3s^2$  to Al  $3p^1$  (1 electron).**

- {2} 10. Answer the following questions:

- a. Which of the following sets of quantum numbers are possible for an electron in an atom and which are impossible. For those impossible indicate why?

- i.  $n = 1, l = 0, m_l = 1, m_s = +2$   
 ii.  $n = 4, l = 2, m_l = 0, m_s = -2$   
 iii.  $n = 3, l = 3, m_l = -2, m_s = -2$

iv.  $n = 4, l = 0, m_l = 0, m_s = 0$

v.  $n = 2, l = 1, m_l = -1, m_s = +2$

i)  $n = 1, l = 0, m_l = 1, m_s = +\frac{1}{2}$  **Not possible**

$m_l$  has a values  $\pm l$ ,  $l = 0$  thus in this case  $m_l$  can only be 0.

ii)  $n = 4, l = 2, m_l = 0, m_s = -\frac{1}{2}$  **Possible**

iii)  $n = 3, l = 3, m_l = -2, m_s = -\frac{1}{2}$  **Not possible**

$l$  takes values of  $n-1$  thus,  $l$  must be 0, 1 or 2

iv)  $n = 4, l = 0, m_l = 0, m_s = 0$  **Not possible**

$m_s$  must be  $\pm \frac{1}{2}$

v)  $n = 2, l = 1, m_l = -1, m_s = +\frac{1}{2}$  **Possible**

{2}

- b. Three species are iso-electronic in that they all contain 36 electrons. One is neutral atom, one is a cation and one is an anion.

- i) Identify the three species using symbols and charge

**Kr Sr<sup>2+</sup> Se<sup>2-</sup> (could just as well be Kr, Rb<sup>+</sup> and Br<sup>-</sup>)**

- ii) Write the ground state configuration for each species.

$$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 = [\text{Kr}]$$

**\*all would have the same configuration**

- iii) Which would you predict to have the largest radius. Explain.

**The largest radius would have to belong to Se<sup>2-</sup>. Since all are isoelectronic (they have the same number of electrons) and thus the same amount of shielding. However, each species above has different numbers of protons. For Se<sup>2-</sup>, their are 36 electrons to be shared with only 34 protons. This imbalance means that their is slightly less attraction for the electrons of Se<sup>2-</sup> for the nucleus and as a result all the electrons of Se<sup>2-</sup> move out from the nucleus, thus increasing its size. For Sr<sup>2+</sup>, we have 38 protons**

attracting only 36 electrons. As a result we see a greater pull from the nucleus and as a result all the electrons of  $\text{Sr}^{2+}$  are pulled closer, thus the radius decreases.

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## Chemistry 4222

### Assignment 2

(Unit 1 - Topics 3 - 4)

Due: November 10, 1998

{30 marks}

Marks

- {1.5} 1. Answer the following questions:
- a. Which of the following would you expect to be polar? Why?
    - i.  $\text{Cl}_2$
    - ii.  $\text{ICl}$
    - iii.  $\text{BF}_3$
    - iv.  $\text{NO}$
    - v.  $\text{SO}_2$
    - vi.  $\text{XeF}_4$
- {1} b.  $\text{AlCl}_3$  readily combines with  $\text{Cl}^-$  to form  $\text{AlCl}_4^-$ . Using Lewis dot diagrams show how this is possible. Why is there a 1- net negative charge on this species?
- {2} 2. Answer the following questions:
- a. When another atom or group of atoms is substituted for one of the hydrogen atoms in benzene,  $\text{C}_6\text{H}_6$ , the boiling point changes. Explain the order of the following boiling points.
    - i.  $\text{C}_6\text{H}_6$ ,  $80^\circ\text{C}$
    - ii.  $\text{C}_6\text{H}_5\text{Cl}$ ,  $132^\circ\text{C}$
    - iii.  $\text{C}_6\text{H}_5\text{Br}$ ,  $156^\circ\text{C}$
    - iv.  $\text{C}_6\text{H}_5\text{OH}$ ,  $182^\circ\text{C}$
- {1} b. Arrange the following chemical substance in order of increasing melting point.
- $\text{NaBr}$ ,  $\text{CO}_2$ ,  $\text{He}$ ,  $\text{C}$ ,  $\text{N}_2$ ,  $\text{C}_4\text{H}_{10}$ ,  $\text{C}_5\text{H}_{12}$
- {6} 3. For each of the following:

- I. Draw a correct Lewis structure
- II. Draw the molecule or ion showing the correct geometry using 3-D conventions
- III. Give the correct VSEPR classification ( $A_xB_yE_z$ )
- IV. Tell what kind of hybrid orbital would be used
- V. Indicate with an arrow the direction of a net dipole moment (if none, write NONE)

- a.  $SO_2^{2-}$
- b.  $IF_5$
- c.  $NF_3$

- {4} 4. In each of the following groups of substances, pick the one that has the given property. Justify each answer.

- a. highest boiling point: NaCl,  $N_2$ ,  $H_2O$
- b. weakest surface tension:  $H_2O$ ,  $CH_3OH$ ,  $C_5H_{12}$  (pentane)
- c. lowest freezing point:  $H_2$ ,  $CH_4$ ,  $I_2$
- d. smallest vapor pressure at  $25^\circ C$ :  $SiO_2$  (network),  $CO_2$ ,  $H_2O$
- e. greatest viscosity:  $CH_3CH_2CH_2CH_3$ ,  $CH_3CH_2OH$ ,  $HOCH_2CH_2OH$
- f. strongest hydrogen bonding:  $NH_3$ ,  $PH_3$ ,  $SbH_3$
- g. greatest  $\Delta H_{vap}$ : HF, HCl, HBr, HI
- h. smallest  $\Delta H_{fus}$ :  $H_2$ ,  $CO_2$ , MgO

- {1} 5. Answer the following questions:

- a. Write nuclear symbols for each of the following:

- i. Lead - 208
- ii. Helium - 5

- {2} b. Complete the following nuclear reactions:

- i. Radon-226 decays by  $\alpha$  emission
- ii. The result of beta decay of an isotope is magnesium-22.

- {1} 6. Answer the following questions:

- a. Calculate the value of the rate constant for thallium-227 which has a half life of 18.2 days.
- b. The half-life of Pa-234 is 6.75 hr. How much (what fraction) of a sample of this isotope remains after 20.25 hrs.

- {1} 7. Answer the following questions:

- a. The half-life of Rn-222 is 3.823 days. What was the original mass of a sample of this isotope if 0.0500g remains after 8 days?

- {1.5} b. A bone is taken out of a cave near Kings Cove, Bonavista Bay and is found

to have a C-14 fraction which is 0.89 of the amount in a living organism. Legend has it that the mythical pirate One-eye Willie was supposed to have buried a treasure in the area about 500 years ago. Could the bone belong to one one-eye's crew left to protect the treasure?(Half life of C-14 is 5730 years)

- {1} 8. Answer the following:
- a. Bombardment of Cl-35 with a neutron produces S-34 and another particle.
  - {1} b. Bombardment of uranium 238 with carbon-12 produces an isotope of element 98 and four identical particles.
  - {1} c. Neutron initiated fission of uranium-235 results in the release of 2 neutrons, the formation of cesium-144 and another nucleus.
- {2} 9. Which do you think would be a greater health hazard: the release of radioactive Sr or radioactive Xe into the environment? Assume the amount of radioactivity is the same in each case. Explain your answer on the basis of the chemical properties of Sr and Xe. Why are the chemical properties of a radioactive substances important in assessing potential health hazards? (Think milk!)
- {2} 10. The proposed system for storing nuclear wastes involves storing the radioactive material in caves or deep mine shafts. One of the most toxic nuclides that must be disposed of is plutonium – 239, which is produced in breeder reactors and has a half-life of 24 100 years. A suitable storage place must be geologically stable long enough for the reactivity of plutonium –239 to decrease to 1% of its original value. How long is this for plutonium-239?
- 
-



## Chemistry 4222

### Solutions to Assignment 2

(Unit 1 - Topics 3 - 4)

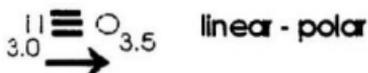
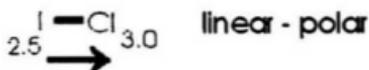
{30 marks}

Marks

{1.5} 1. Answer the following questions:

a. Which of the following would you expect to be polar? Why?

- i.  $\text{Cl}_2$
- ii.  $\text{ICl}$
- iii.  $\text{BF}_3$
- iv.  $\text{NO}$
- v.  $\text{SO}_2$
- vi.  $\text{XeF}_4$

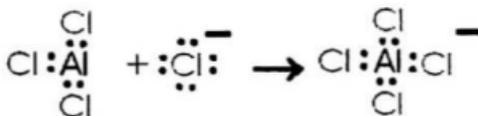


$\text{SO}_2$  \*see text 8.14 p 393

$\text{XeF}_4$  \* see text p 392 - non-polar

{1}

- b.  $\text{AlCl}_3$  readily combines with  $\text{Cl}^-$  to form  $\text{AlCl}_4^-$ . Using Lewis dot diagrams show how this is possible. Why is there a 1- net negative charge on this species?



This type of bonding is known as a co-ordinate covalent bond. Both sets of electrons in the new Al-Cl bond come from  $\text{Cl}^-$ . The addition of  $\text{Cl}^-$  adds to the stability of the new molecule. The shape of  $\text{AlCl}_3$  is trigonal planar. When the  $\text{Cl}^-$  attaches we see a tetrahedral arrangement indicating  $\text{sp}^3$  hybridization has occurred.

{2}

2. Answer the following questions:

- a. When another atom or group of atoms is substituted for one of the hydrogen atoms in benzene,  $\text{C}_6\text{H}_6$ , the boiling point changes. Explain the order of the following boiling points.

- i.  $\text{C}_6\text{H}_6$ ,  $80^\circ\text{C}$
- ii.  $\text{C}_6\text{H}_5\text{Cl}$ ,  $132^\circ\text{C}$
- iii.  $\text{C}_6\text{H}_5\text{Br}$ ,  $156^\circ\text{C}$
- iv.  $\text{C}_6\text{H}_5\text{OH}$ ,  $182^\circ\text{C}$

(i)  $\text{C}_6\text{H}_6$ ,  $80^\circ\text{C}$

**LDF(42 electrons)**

(ii)  $\text{C}_6\text{H}_5\text{Cl}$ ,  $132^\circ\text{C}$

**LDF(52 electrons), dipole-dipole**

**- increased boiling point due to extra intermolecular forces.**

(iii)  $\text{C}_6\text{H}_5\text{Br}$ ,  $156^\circ\text{C}$

**LDF(70 electrons), dipole dipole**

**-even though the dipole forces are weaker here than above, the LDF caused by the large Br atom increases the BP significantly**

(iv)  $C_6H_5OH$ ,  $182^\circ C$

**LDF (44 electrons), dipole dipole, hydrogen bonding**

**- the key to such a large increase in BP is due to the presence of Hydrogen bonding which is far stronger than any other intermolecular force.**

{1}

- b. Arrange the following chemical substance in order of increasing melting point.

NaBr,  $CO_2$ , He, C,  $N_2$ ,  $C_4H_{10}$ ,  $C_5H_{12}$

**lowest BP He LDF(2)**

**$N_2$  LDF(14)**

**$CO_2$  LDF(22)**

**$C_4H_{10}$  LDF(34)**

**NaBr ionic bonds(very strong) $C_5H_{12}$**

*\*ionic forces are much more stronger than all of H-bonding, D-D forces, and LDF combined.*

**Highest C \* if Diamond (network covalent extremely strong)(highest)**

**\*if graphite or coal forces are much weaker and may be weaker than NaBr.**

{6}

3. For each of the following:

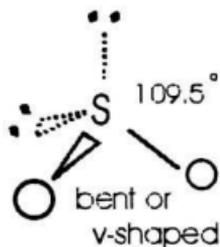
- I. Draw a correct Lewis structure
- II. Draw the molecule or ion showing the correct geometry using 3-D conventions
- III. Give the correct VSEPR classification ( $A_xB_yE_z$ )
- IV. Tell what kind of hybrid orbital would be used
- V. Indicate with an arrow the direction of a net dipole moment (if none, write NONE)

a.  $SO_2^{2-}$

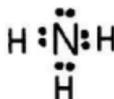
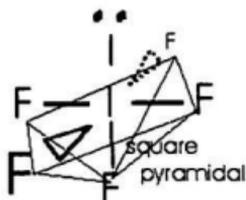
b.  $IF_5$

c.  $\text{NF}_3$ 

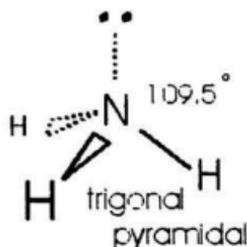
4 sets of electrons  
-- hybridization  $\text{sp}^3$



6 sets of electrons  
-- hybridization  $\text{sp}^3\text{d}^2$



4 sets of electrons  
-- hybridization  $\text{sp}^3$



{4} 4. In each of the following groups of substances, pick the one that has the given property. Justify each answer.

a. highest boiling point:  $\text{NaCl}$ ,  $\text{N}_2$ ,  $\text{H}_2\text{O}$

**$\text{NaCl}$  – ionic forces (strong)**

b. weakest surface tension:  $\text{H}_2\text{O}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{C}_5\text{H}_{12}$  (pentane)

**$\text{C}_5\text{H}_{12}$  (pentane) – only has LDF and is non-polar**

c. lowest freezing point:  $\text{H}_2$ ,  $\text{CH}_2$ ,  $\text{I}_2$

**$\text{H}_2$  - has weaker intermolecular forces LDF(2).**

d. smallest vapor pressure at  $25^\circ\text{C}$ :  $\text{SiO}_2$  (network),  $\text{CO}_2$ ,  $\text{H}_2\text{O}$

**$\text{SiO}_2$  (network) – molecules are tightly bound causing vaporization to be restricted.**

e. greatest viscosity:  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ ,  $\text{CH}_3\text{CH}_2\text{OH}$ ,  $\text{HOCH}_2\text{CH}_2\text{OH}$

**$\text{HOCH}_2\text{CH}_2\text{OH}$  – ethandiol has the greatest amount of H bonding thus greatest intermolecular attraction. This would make it thicker (more viscous)**

f. strongest hydrogen bonding:  $\text{NH}_3$ ,  $\text{PH}_3$ ,  $\text{SbH}_3$

**$\text{NH}_3$  – greatest dipole between N and H causes the H bonding.**

g. greatest  $\Delta H_{\text{vap}}$ :  $\text{HF}$ ,  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{HI}$

**$\text{HF}$  – strongest intermolecular forces (LDF, D-D, and H bonding), greater attractive forces holding molecules together, would require much more energy to vaporize the molecules (figure 10.4 pp 446)**

h. smallest  $\Delta H_{\text{fus}}$ :  $\text{H}_2$ ,  $\text{CO}_2$ ,  $\text{MgO}$

**$\text{H}_2$  would have the smallest.  $\Delta H$  fusion refers to the energy required to disrupt the forces keeping the solid together. Since  $\text{H}_2$  has the least amount of intermolecular forces, its solid would be the easiest to disrupt.**

{1} 5. Answer the following questions:

a. Write nuclear symbols for each of the following:

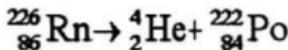
i. Lead - 208

ii. Helium - 5

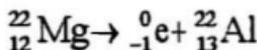


{2} b. Complete the following nuclear reactions:

i. Radon-226 decays by  $\alpha$  emission



ii. The result of beta decay of an isotope is magnesium-22.



{1} 6. Answer the following questions:

a. Calculate the value of the rate constant for thallium-227 which has a half life of 18.2 days.

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{18.2\text{d}} = 0.0381\text{d}^{-1}$$

{1} b. The half-life of Pa-234 is 6.75 hr. How much (what fraction) of a sample of this isotope remains after 20.25 hrs.

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{6.75\text{h}} = 0.103\text{h}^{-1}$$

$$\ln\left(\frac{N}{N_0}\right) = -kt = -0.103\text{h}^{-1} \cdot 20.25\text{h} = -2.09$$

$$\left(\frac{N}{N_0}\right) = e^{-2.09} = 0.125 \quad \text{or} \quad \frac{1}{8}$$

{1} 7. Answer the following questions:

a. The half-life of Rn-222 is 3.823 days. What was the original mass of a sample of this isotope if 0.0500g remains after 8 days?

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{3823d} = 0.1813d^{-1}$$

$$\ln\left(\frac{N}{N_0}\right) = -kt$$

$$\ln\left(\frac{0.0500g}{N_0}\right) = -0.1813d^{-1} \times 8.00d = -1.450$$

$$\left(\frac{0.0500g}{N_0}\right) = e^{-1.450} = 0.2345$$

$$N_0 = \frac{0.0500g}{0.2345} = 0.213g$$

{1.5}

- b. A bone is taken out of a cave near Kings Cove, Bonavista Bay and is found to have a C-14 fraction which is 0.89 of the amount in a living organism. Legend has it that the mythical pirate One-eye Willie was supposed to have buried a treasure in the area about 500 years ago. Could the bone belong to one one-eye's crew left to protect the treasure?(Half life of C-14 is 5730 years)

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{5730yr} = 1.209 \times 10^{-4} yr^{-1}$$

$$\ln\left(\frac{N}{N_0}\right) = -kt$$

$$\ln(0.89) = -1.209 \times 10^{-4} yr^{-1} \times t$$

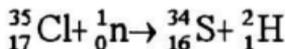
$$t = \frac{-0.1165}{-1.209 \times 10^{-4} yr^{-1}} = 963yr$$

**In order for the C-14 fraction to be 0.89% the bone must be atleast 963 yrs old. Since the legend places one-eye Willie to about 500 years ago, it would be**

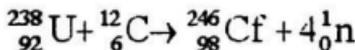
**impossible for the bone to belong to one of one-eye's crew!**

- {1} 8. Answer the following:

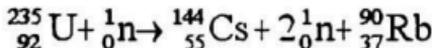
a. Bombardment of Cl-35 with a neutron produces S-34 and another particle.



- {1} b. Bombardment of uranium 238 with carbon-12 produces an isotope of element 98 and four identical particles.



- {1} c. Neutron initiated fission of uranium-235 results in the release of 2 neutrons, the formation of cesium-144 and another nucleus.

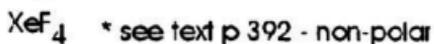
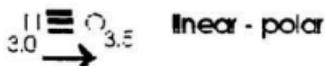
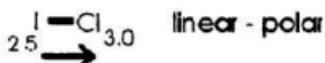


- {2} 9. Which do you think would be a greater health hazard: the release of radioactive Sr or radioactive Xe into the environment? Assume the amount of radioactivity is the same in each case. Explain your answer on the basis of the chemical properties of Sr and Xe. Why are the chemical properties of a radioactive substances important in assessing potential health hazards? (Think milk!)

**Release of Sr is probably more harmful. Xe is chemically unreactive. Strontium is in the same family as calcium and could be absorbed and concentrated in the body in a fashion similar to Ca (radioactive Sr gets in the grass, cows eat the grass, make milk, we drink the milk!). This puts radioactive Sr in the bones and teeth. This will stay in the bones for a very long time. Of importance here is that red blood cells are produced in the bone marrow! Xe would not be readily incorporated into the body.**

**The chemical properties determine where radioactive material may be concentrated in the body or how easily it can be excreted. The length of time of exposure and what is exposed to the radiation significantly affects the health hazard. (see Zumdahl 21.44)**

- {2} 10. The proposed system for storing nuclear wastes involves storing the radioactive material in caves or deep mine shafts. One of the most toxic nuclides that must be disposed of is plutonium - 239, which is produced in breeder reactors and has a half-life of 24 100 years. A suitable storage place must be geologically stable long enough for the reactivity of plutonium -239 to decrease to 1% of its original value. How long is this for plutonium-239?



**Appendix F: Unit Tests.**

**Chemistry 4222**  
**(Unit I - Topics 1& 2)**  
**1998-99**

Time: 55 minutes  
 Total Value 30 Marks

**SECTION A**

**Instructions:** *DO NOT PLACE YOUR ANSWERS ON THIS SHEET. Instead use the answer sheet to be found on p. 4 of this test. For questions 1 - 13 put the appropriate letter in the blanks on the answer sheet.*

1. The percent, by mass, of phosphorus in  $\text{Ca}_3(\text{PO}_4)_2$  is;

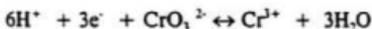
- a) 10%                      b) 20%  
 c) 30%                      d) 40%

2. When properly balanced under acidic conditions, the sum of all the coefficients (numbers used to balance!) in the half reaction below will be;



- a) 12                      b) 14  
 c) 8                      d) 5  
 e) none of these.

3. 2-propanol,  $\text{C}_3\text{H}_7\text{OH}$  can be oxidized to acetone,  $\text{C}_3\text{H}_6\text{O}$ , under acidic conditions. The two half reactions for this process are given below;



In this reaction, 4 moles of  $\text{CrO}_3^{2-}$  would react exactly to completion with;

- a) 4 moles of 2-propanol                      b) 2 moles of 2-propanol  
 c) 6 moles of 2-propanol                      d) 3 moles of 2-propanol  
 e) 1 moles of 2-propanol

4. Consider the reaction;  $\text{C} + \text{H}_2\text{O} \leftrightarrow \text{CO} + \text{H}_2$  Which one of the following statements is **FALSE**?

- a) carbon is oxidized in the reaction  
 b) oxygen is reduced in the reaction  
 c) carbon monoxide is the name of one product in this reaction  
 d) the oxidation number of the product hydrogen is 0

5. A compound with empirical formula  $\text{CHO}_2$  has a molar mass of 90.0 g/mol. What is the molecular formula?  $\text{CHO}_2$
- a)  $\text{C}_3\text{H}_2\text{O}_4$                       b)  $\text{C}_2\text{HO}_2$   
b)  $\text{C}_3\text{H}_6\text{O}$                         d)  $\text{CHO}_2$
6. What is the oxidation number of Cr in  $\text{Cr}_2\text{O}_7^{2-}$  ?
- a) 0                                      b)  $6^+$   
c)  $12^+$                                 d)  $14^+$
7. A certain gas is an oxide of Nitrogen that contains 30.15% N by mass, what is the formula of this gas?
- a)  $\text{N}_2\text{O}_4$                               b)  $\text{NO}_2$   
c)  $\text{NO}$                                  d)  $\text{N}_2\text{O}$   
e)  $\text{N}_2\text{O}_5$
8. Which one of the following types of radiation has the shortest wavelength, the greatest energy, and the highest frequency?
- a) ultraviolet radiation              b) visible red light  
c) infra-red radiation                d) visible blue light  
e) none, because short wavelength is associated with low energy and low frequency
9. Green light has a wavelength of  $5.50 \times 10^2 \text{ nm}$ . The energy of a photon of green light is ( $1 \text{ nm} = 1 \times 10^{-9} \text{ m}$ ):
- a)  $3.64 \times 10^{-18} \text{ J}$                       b)  $2.17 \times 10^5 \text{ J}$   
c)  $3.61 \times 10^{-19} \text{ J}$                       d)  $1.09 \times 10^{-19} \text{ J}$   
e)  $5.45 \times 10^{12} \text{ J}$
10. If  $n = 2$ , how many orbitals are possible?
- a) 2                                      b) 3  
c) 4                                      d) 6  
e) 8
11. Which of the following atoms would have the largest second ionization energy?
- a) Mg                                      b) Cl  
c) S                                        d) Ca  
e) Na

12. Which of the following is the electron configuration of an excited atom that is likely to emit a quantum of energy?
- a)  $1s^2 2s^2 2p^6 3s^2 3p^1$
  - b)  $1s^2 2s^2 2p^6 3s^2 3p^5$
  - c)  $1s^2 2s^2 2p^6 3s^2$
  - d)  $1s^2 2s^2 2p^6 3s^1$
  - e)  $1s^2 2s^2 2p^6 3s^1 3p^1$

13. Consider the following orderings:

- I.  $Al < Si < P < S$
- II.  $Be < Mg < Ca < Sr$
- III.  $I < Br < Cl < F$
- IV.  $Na^+ < Mg^{2+} < Al^{3+} < Si^{4+}$

Which of these give a correct trend in size?

- a) I
- b) II
- c) III
- d) IV
- e) II and IV.

**Fill In:** Give the electron configurations for the following:

14) S atom

15)  $Cu^+$  ion

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_\_\_ of \_\_\_ 4  
 C. 4222 Unit I Test I

## Answer Sheet for Sections A and B

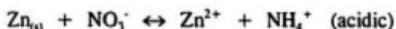
{15} Section A

- |         |         |         |          |           |
|---------|---------|---------|----------|-----------|
| 1. ____ | 4. ____ | 7. ____ | 10. ____ | 13. ____  |
| 2. ____ | 5. ____ | 8. ____ | 11. ____ | 14. _____ |
| 3. ____ | 6. ____ | 9. ____ | 12. ____ | 15. _____ |

### SECTION B

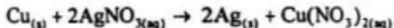
**Instructions:** *Place your answers and solutions in the spaces provided. {20 marks}*

- {3} 1) Balance the following redox reaction, identify the oxidizing agent, reducing agent, the substance oxidized and the substance reduced.



Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_\_ of \_\_ 5  
C. 4222 Unit I Test 1

- 2) A chemistry student wishes to produce silver in a chemical reaction by mixing a solution of silver nitrate with copper metal.



- {2} a) Find the limiting reagent if 4.0 g of copper metal is placed in 100.0 mL of 1.0 mol/L silver nitrate.
- {2} b) What mass of silver would be produce given the amounts in (ii) above.
- {2} 3) a) The calcium atom is much larger than the calcium ion, while the fluorine atom is much smaller than the fluorine ion. Explain this natural occurrence.

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_\_\_ of \_\_\_ 6  
C. 4222 Unit I Test I

- {2} b) The successive ionization energies of element A are given below. To which periodic group does this element belong? Why?

Ionization	Energy, kcal/mol
first	241.8
second	454.9
third	695.6
fourth	1184.6
fifth	1499.5
sixth	5084.4
seventh	6073.9
Eighth	7133.8

- {4} 4 Write net-ionic equations for any TWO (2) of the following reactions:

- a) a strip of zinc is added to a solution of 6 M hydrobromic acid.
- b) Rubidium reacts with water producing a gas and a basic solution.
- c) The reaction of phosphoric acid with potassium hydroxide

Chemistry 4222  
(Unit II -Topics 1 Through 3)  
1998-99

Time: 55 minutes  
Total Value 30 Marks

**SECTION A**

**Instructions:** *DO NOT PLACE YOUR ANSWERS ON THIS SHEET. Instead use the answer sheet to be found on p. 5 of this test. For questions 1 - 15 put the appropriate letter in the blanks on the answer sheet.*

- What is the volume occupied of 0.50 moles of a gas, at a temperature of 27°C and a pressure of 202.6 kPa?
 

a) 6.2 L	b) 0.55 L
c) 0.16 L	d) 1.8 L
- A mixture of 1.00 g of  $H_{2(g)}$  and 1.00 g of  $He_{(g)}$  exerts a pressure of 0.480 atm. What is the partial pressure due to  $He$ ?
 

a) 0.161 atm	b) 0.219 atm
c) 0.745 atm	d) not enough information.
- The diffusion rate of an unknown gas is 31.50 mL/min. Under identical experimental conditions, the diffusion rate of  $O_{2(g)}$  is found to be 30.50 mL/min. What is the identity of the unknown gas?
 

a) $CH_4$ ( $M_w = 16.04$ )	b) $CO$ ( $M_w = 28.01$ )
c) $NO$ ( $M_w = 30.01$ )	d) $CO_2$ ( $M_w = 44.01$ )
e) $NO_2$ ( $M_w = 46.01$ )	
- A sample of  $O_{2(g)}$  with mass 1.25 g is collected over water at 25°C. A volume of 1.012L was recovered. If the partial pressure of water ( $P_{H_2O}$ ) at 25°C is 3.17 kPa, What was the barometric pressure at the time the gas was collected?
 

a) 95.7 kPa	b) 98.9 kPa
c) 101.3 kPa	d) 92.5 kPa
- A sample of Kr gas at conditions of 1 atm, 20.0 L, and 300 K is allowed to change to conditions of 40.0 L and 150 K. The new pressure is :
 

a) 0.25 atm	b) 0.50 atm
c) 1.0 atm	d) 2.0 atm
e) 4.0 atm	

## C. 4222 Unit II Test 3

2

6. A 0.500 g sample of gaseous  $\text{Ni}(\text{CO})_x$  (where  $x$  is 2, 3, 4, or 5) in a 0.100L bulb generates a pressure of 552 mmHg at 30 °C. What is the correct formula of  $\text{Ni}(\text{CO})_x$  ?

- a)  $\text{Ni}(\text{CO})_2$                       b)  $\text{Ni}(\text{CO})_3$   
 c)  $\text{Ni}(\text{CO})_4$                       d)  $\text{Ni}(\text{CO})_5$

7. A solution is prepared by mixing 1.00 g of ethanol ( $\text{C}_2\text{H}_5\text{OH}$  M.W. = 46.07 g/mol) with 100.0 g of water to give a final volume of 101.0 mL. What is the mole fraction of ethanol in this mixture?

- a) 0.00389                          b) 0.215  
 c) 0.217                              d) 0.990

8. At a certain temperature the diffusion rate of helium is 0.21 m/s. Under the same conditions;

- i) the diffusion rate of hydrogen is 0.15 m/s  
 ii) the diffusion rate of hydrogen is 0.30 m/s  
 iii) the diffusion rate of  $\text{CH}_4$  will be higher.  
 iv) the diffusion rate of  $\text{NH}_3$  will be lower.

- a) none of the above                      b) (i) and (ii)  
 c) (ii) and (iii)                          d) (ii) and (iv)

9. 1.00 mg of an unknown protein was dissolved in enough water to make 1.00 mL of solution. At 25.0 °C the osmotic pressure was found to be  $1.47 \times 10^{-3}$  atm. What is the molar mass of the protein?

- a)  $6.01 \times 10^5$  g/mol                      b) 100 g/mol  
 c) 12.01 g/mol                          d)  $1.66 \times 10^4$  g/mol

10. Which of the following are true statements;

- i)  $R = (PV) / (nT)$   
 ii) The closer a gas is to the liquid state, the more it will deviate from the ideal gas law.  
 iii)  $\text{H}_2\text{O}$  behaves more ideally than  $\text{H}_2$   
 iv) A balloon filled with argon is smaller than an identical balloon filled with helium (assume constant T, P and n).

- a) all of the above                      b) (i) and (ii)  
 c) (ii) and (iv)                          d) (i), (ii) and (iv)

11. Which gases would have the same rate of diffusion?

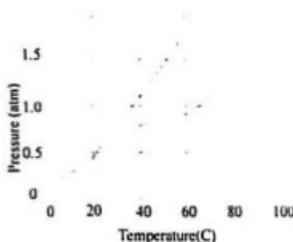
- i)  $C_2H_2$
- ii)  $N_2$
- iii)  $CO$
- iv)  $CH_4$

- a) i and ii
- b) ii and iii
- c) iii and iv
- d) i and iv

12. Which type of water-based solution would be likely to have the lowest freezing point?

- a) pure water
- b) 1 M sucrose (non-electrolyte)
- c) 1 M  $Na_3PO_4$  (electrolyte)
- d) 1 M  $NaCl$  (electrolyte)

13. The phase diagram for the pure substance X is shown to the right. The temperature of a sample of pure solid X is slowly raised from  $10^\circ C$  to  $100^\circ C$  at a constant pressure of 0.5 atm. What is the expected behavior of the substance?



- (a) It first melts to a liquid and then it boils at about  $70^\circ C$ .
- (b) It first melts to a liquid and then it boils at about  $30^\circ C$ .
- (c) It melts to a liquid at a temperature of about  $20^\circ C$  and remains a liquid until the temperature is greater than  $100^\circ C$ .
- (d) It sublimates to a vapor at an equilibrium temperature of about  $20^\circ C$ .
- (e) It remains a solid until the temperature is greater than  $100^\circ C$ .

14. Under what conditions will club soda be likely to retain its "fizz" longer? (i.e., under what conditions will the gas remain in the liquid longer?)

- a) low pressure and low temperature
- b) high pressure and low temperature
- c) low pressure and high temperature
- d) high pressure and high temperature
- e) none of the above, pressure and temperature have nothing to do with it.

15. Which of the following is **TRUE** concerning a 1.0 L sample of  $\text{SO}_2$  gas (molar mass 64 grams) and a 1.0 L sample of  $\text{CH}_4$  gas (molar mass 16grams) when each gas is at standard temperature and pressure.
- a) There are four times as many  $\text{SO}_2$  molecules as  $\text{CH}_4$  molecules.
  - b) The sample of  $\text{SO}_2$  gas weighs the same as the sample of  $\text{CH}_4$  gas.
  - c) The average kinetic energy of the  $\text{CH}_4$  molecules is greater than that of the  $\text{SO}_2$  molecules
  - d) The average kinetic energy of the  $\text{SO}_2$  molecules is greater than that of the  $\text{CH}_4$  molecules.
  - e) The two samples of gas contain an equal number of molecules.

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_\_\_ of \_\_\_ 5  
C. 4222 Unit II Test 3

### Answer Sheet for Sections A and B

{15} **Section A**

1. \_\_\_\_ 4. \_\_\_\_ 7 \_\_\_\_ 10. \_\_\_\_ 13. \_\_\_\_  
2. \_\_\_\_ 5. \_\_\_\_ 8. \_\_\_\_ 11. \_\_\_\_ 14. \_\_\_\_  
3. \_\_\_\_ 6. \_\_\_\_ 9. \_\_\_\_ 12. \_\_\_\_ 15. \_\_\_\_

### SECTION B

**Instructions:** *Place your answers and solutions in the spaces provided.*

- {2} 1. a) Differentiate between Ideal Gases and Real Gases. What conditions favour Ideal gas behaviour and why?
- {2} b) At extremely high altitudes it is observed that water boils at temperatures much lower than 100°C. How do you account for this observation.
- {2} c) Account for the fact that the freezing point of sea water is depressed by a couple of degrees.

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_ of \_ 6  
C. 4222 Unit II Test 3

- 2) A sample of  $\text{KClO}_{3(s)}$  was decomposed by the following reaction:



The oxygen produced was collected by displacement of water at  $22^\circ\text{C}$  at a total pressure of 754 mmHg. The volume of the gas collected was 0.650 L. The vapor pressure due to water at  $22^\circ\text{C}$  is 21 mmHg.

- {2} a) Calculate the partial pressure of  $\text{O}_{2(g)}$  collected.

- {2} b) Calculate the mass of  $\text{KClO}_3$  decomposed.

3. The first preparation of sulfanilamide (one of the sulfa drugs) was published in 1908. According to the abstract, the mass composition of the compound is 41.84% C, 4.68% H, 16.27% N, 18.58% O and 18.62% S. A solution of 1.27 g sulfanilamide in 15.0 g of 1,4-dichlorobenzene (f.p. =  $53.1^\circ\text{C}$ ,  $K_f = 7.10$ ) has a freezing point of  $49.6^\circ\text{C}$ .

- {3} (a) What molar mass of this compound?

- {2} (b) What is the molecular formula of this compound?

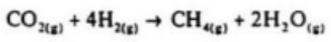
Chemistry 4222  
(Unit III - Topics 3 through Topic 4.1)  
1998-99

Time: 55 minutes  
Total Value 30 Marks

SECTION A

Instructions: **DO NOT PLACE YOUR ANSWERS ON THIS SHEET.** Instead use the answer sheet to be found on p. 6 of this test. For questions 1 - 15 put the appropriate letter in the blanks on the answer sheet.

1. For the reaction below, if the rate of formation of CH<sub>4</sub> is 16.0 moles per hour, then the rate of disappearance of H<sub>2</sub> is:



- a) 2 mol/hr
- b) 4 mol/hr
- c) 8 mol/hr
- d) 64 mol/hr
- e) 256 mol/hr

2. For the reaction A + B → products it is found that;

- i. when [A] is doubled and [B] is held constant the initial rate doubles, and
- ii. when [A] is held constant and [B] is halved the initial rate also halves.

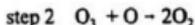
What are the units for the rate constant, k, for this reaction? ([A] and [B] are in mol·L<sup>-1</sup> and rate has units mol·L<sup>-1</sup>·s

- a) mol<sup>2</sup> · L<sup>2</sup> · s<sup>-2</sup>
- b) mol<sup>2</sup> · L<sup>-2</sup> · s<sup>-1</sup>
- c) mol · L<sup>-1</sup>
- d) mol<sup>-2</sup> · L<sup>2</sup> · s<sup>-1</sup>
- e) mol<sup>-1</sup> · L · s

3. The catalyzed pathway in a reaction mechanism has a \_\_\_\_\_ activation energy and thus causes a \_\_\_\_\_ reaction rate.

- a. higher, lower
- b. higher, higher
- c. lower, higher
- d. lower, steady
- e. higher, steady

4. The decomposition of ozone may occur through the two-step mechanism shown:



The oxygen atom is considered to be a(n)

- reactant
  - product
  - catalyst
  - reaction intermediate
  - activated complex
5. The reaction  $2\text{A} + \text{B} \rightarrow \text{C}$  has the following proposed mechanism:



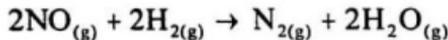
If step 2 is the rate-determining step, then the rate of formation of C should equal:

- $k[\text{A}]$
  - $k[\text{A}]^2 [\text{B}]$
  - $k[\text{A}]^2 [\text{B}]^2$
  - $k[\text{A}][\text{B}]$
  - $k[\text{A}][\text{B}]^2$
6. Consider the reaction:  $2\text{N}_2\text{O}_{5(\text{g})} \rightarrow 4\text{NO}_{2(\text{g})} + \text{O}_{2(\text{g})}$

Two equivalent ways of expressing the general average rate of this reaction are:

- $\frac{-\Delta[\text{NO}_2]}{4\Delta t}$  and  $\frac{-\Delta[\text{O}_2]}{\Delta t}$
- $\frac{-\Delta[\text{N}_2\text{O}_5]}{2\Delta t}$  and  $\frac{\Delta[\text{O}_2]}{2\Delta t}$
- $\frac{\Delta[\text{NO}_2]}{4\Delta t}$  and  $\frac{-\Delta[\text{N}_2\text{O}_5]}{2\Delta t}$
- $k[\text{N}_2\text{O}_5]^2$  and  $k[\text{NO}_2]^4[\text{O}_2]$

7. The following data have been obtained at 1099 K for the reaction :

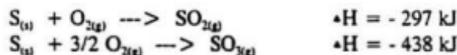


Initial $[\text{H}_2]$ ( $\text{M} \times 10^3$ )	Initial $[\text{NO}]$ ( $\text{M} \times 10^3$ )	Initial Rate ( $\text{M s}^{-1} \times 10^7$ )
5.84	4.40	14.6
5.84	2.20	3.65
2.92	4.40	7.30

What is the rate law for this reaction?

- a) Rate =  $k[\text{H}_2][\text{NO}]$                       b) Rate =  $k[\text{H}_2]^2[\text{NO}]^2$   
 c) Rate =  $k[\text{H}_2]^2[\text{NO}]$                     d) Rate =  $k[\text{H}_2][\text{NO}]^2$   
 e) Rate =  $k \frac{[\text{H}_2][\text{NO}]^2}{[\text{N}_2][\text{H}_2\text{O}]^2}$

8. Given the following reaction:



What is the heat of reaction for;  $2 \text{SO}_{2(g)} + \text{O}_{2(g)} \rightarrow 2 \text{SO}_{3(g)}$

- a) - 282 kJ  
 b) - 297 kJ  
 c) - 735 kJ  
 d) - 890 kJ  
 e) - 1470 kJ
9. What is the total heat required to change 10.0 g of ice at  $-15^\circ\text{C}$  into liquid water at  $0^\circ\text{C}$ .
- a) 307.8 J                      b) 304.5 kJ  
 c) 2.68 kJ                     d) 3.64 kJ
10. A sample of methanol, with a specific heat capacity of  $2.51 \text{ J}/(\text{g}^\circ\text{C})$  required 27.1 kJ of energy to be heated from  $22.0^\circ\text{C}$  to  $52.0^\circ\text{C}$ . The mass of the methanol is:
- a) 208 g                        b) 359 g  
 c) 491 g                        d) 2.78 kg

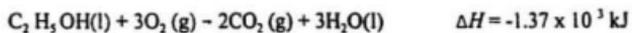
11. Two metals of equal mass with different heat capacities are subjected to the same amount of heat. Which undergoes the smallest change in temperature?
- The metal with the higher heat capacity.
  - The metal with the lower heat capacity.
  - Both undergo the same change in temperature.
  - You need to know the initial temperatures of the metals.
  - You need to know which metals you have.
12. In the lab, you mix two solutions (each originally at the same temperature) and the temperature of the resulting solution decreases. Which of the following is true?
- The chemical reaction is releasing energy.
  - The energy released is equal to  $s \times m \times T$ .
  - The chemical reaction is absorbing energy.
  - The chemical reaction is exothermic.
  - More than one of these.
13. Consider the following processes:

	$\Delta H$ (kJ/mol)
$1/2A \rightarrow B$	150.
$3B \rightarrow 2C + D$	-125
$E + A \rightarrow 2D$	350.

Calculate  $\Delta H$  for:  $B + D \rightarrow E + 2C$

- 325 kJ/mol
  - 525 kJ/mol
  - 175 kJ/mol
  - 325 kJ/mol
  - none of these
14. The heat combustion of acetylene,  $C_2H_2(g)$ , at  $25^\circ C$ , is  $-1299$  kJ/mol. At this temperature,  $\Delta H^\circ$  values for  $CO_2(g)$  and  $H_2O(l)$  are  $-393$  and  $-286$  kJ/mol, respectively. Calculate the heat of formation,  $\Delta H^\circ_f$ , for acetylene.
- 2376 kJ/mol
  - 625 kJ/mol
  - 227 kJ/mol
  - 625 kJ/mol
  - none of these

15. Consider the reaction



When a 15.1-g sample of ethyl alcohol (molar mass = 46.1 g/mol) is burned, how much energy is released as heat?

- a) 0.449 kJ
- b)  $2.25 \times 10^3$  kJ
- c)  $4.49 \times 10^2$  kJ
- d)  $1.02 \times 10^3$  kJ
- e) 196 kJ

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_\_\_ of \_\_\_ 6  
 C. 4222 Unit III Test 5

Answer Sheet for Sections A and B

{15} Section A

1. \_\_\_\_\_ 4. \_\_\_\_\_ 7. \_\_\_\_\_ 10. \_\_\_\_\_ 13. \_\_\_\_\_

2. \_\_\_\_\_ 5. \_\_\_\_\_ 8. \_\_\_\_\_ 11. \_\_\_\_\_ 14. \_\_\_\_\_

3. \_\_\_\_\_ 6. \_\_\_\_\_ 9. \_\_\_\_\_ 12. \_\_\_\_\_ 15. \_\_\_\_\_

**SECTION B**

**Instructions:** Place your answers and solutions in the spaces provided.

1 The reaction  $2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2$  is first order with respect to  $\text{N}_2\text{O}_5$ .

- {1} (a) Use the axis at the right, complete the graph that represents the change in  $[\text{N}_2\text{O}_5]$  over time as the reaction proceeds.

Initial ●  
 $[\text{N}_2\text{O}_5]$

- {1.5} (b) Describe how the graph in (a) could be used to find the reaction rate at a given time,  $t$ .

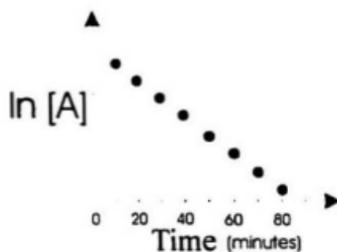
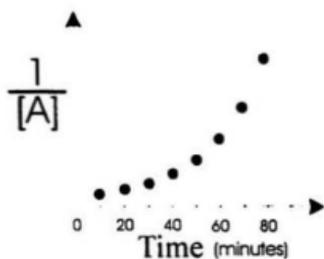
Time ►

- {1.5} (c) Considering the rate law and the graph in (a), describe how the value of the rate constant,  $k$ , could be determined.

- {2} (d) If more  $\text{N}_2\text{O}_5$  were added to the reaction mixture at constant temperature, what would be the effect on the rate constant,  $k$ ? Explain.

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p. of \_\_\_\_\_ 7  
 C. 4222 Unit III Test 5

2. Data for the chemical reaction  $2A \rightarrow B + C$  were collected by measuring the concentration of A at 10-minute intervals for 80 minutes. The following graphs were generated from analysis of the data.

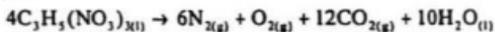


Use the information on the graphs to answer the following data.

- {2 } (a) Write the rate law expression for the reaction. Justify your answer.
- {2 } (b) Describe how to determine the value of the rate constant for the reaction.

Name: \_\_\_\_\_ Teacher: \_\_\_\_\_ Site: \_\_\_\_\_ p \_ of \_ 8  
 C. 4222 Unit III Test 5

3. Nitro glycerine,  $C_3H_5(NO_3)_3$  (molar mass  $227.1 \text{ g}\cdot\text{mol}^{-1}$ ), decomposes according to the following reaction:



2.271 g of nitroglycerine is decomposed in a bomb calorimeter containing about 1 kg of water. The total heat capacity of the bomb calorimeter was  $4.34 \text{ kJ}\cdot\text{C}^{-1}$ . The temperature of the calorimeter was found to increase from  $22.45 \text{ }^\circ\text{C}$  to  $25.77 \text{ }^\circ\text{C}$ .

- {3} (a) Calculate the amount of heat produced when 1.00 mole of nitroglycerine explodes.

- {2} (b) Calculate the enthalpy of formation,  $\Delta H_f$ , for nitroglycerine given that:  $\Delta H_f(H_2O) = -285.9 \text{ kJ}\cdot\text{mol}^{-1}$  and  $\Delta H_f(CO_2) = -393.5 \text{ kJ}\cdot\text{mol}^{-1}$ .

**Appendix G: Sample E-mail Correspondence.**

**From:** jennifer Hookey <jenniferhookey@hotmail.com>  
**To:** bewells@calvin.stemnet.nf.ca <bewells@calvin.stemnet.nf.ca>  
**Date:** Friday, September 18, 1998 1:49 PM  
**Subject:** chem 4222

Hello Mr Wells,

I am in your chem 4222 class and am somewhat frustrated with the situation. I am trying to keep in touch as are the rest of the class. It is hard though as we do not know if we are in the same boat as everyone else. We have no supervision so we have not done our lab yet. I have read the sections in the book and done the test on the cd rom. I don't know if that is enough, but there is not much more that I can do. Email me back with any info that could help me, or if there is nothing more to do, could you let me know as well? Thank you,

Jennifer Hookey

---

Get Your Private, Free Email at <http://www.hotmail.com>

**From:** jody spurrell <jodyspurrell@hotmail.com>  
**To:** bewells@calvin.stemnet.nf.ca <bewells@calvin.stemnet.nf.ca>  
**Date:** Monday, September 21, 1998 1:51 PM  
**Subject:** Chemistry 4222

Mr. Wells,

We went into the Chemistry program this morning during second period, but the program wouldn't work. We got in as far as the chat home page but that's it. We had the chemistry teacher in today, he checked to see if there was anything he could help us with, but there wasn't very many problems. We started lesson 5, and will have it completed for next class. Now what about our labs, will we get the teacher here to help us with them? Mr. Ingram has most of his prep. periods during the same time as our scheduled classes. Please let me know.

Jody Spurrell  
Bishop White

---

Get Your Private, Free Email at <http://www.hotmail.com>

**From:** Brian Wells <bewells@calvin.sternnet.nf.ca>  
**To:** jody spurrell <jodyspurrell@hotmail.com>  
**Date:** Monday, September 21, 1998 2:42 PM  
**Subject:** Re: Chemistry 4222

---

Hello Jody,

I guess you are talking on behalf of the other students up there in P.R.

It's good to hear from you.

Lesson five is good. No problems is good. Keep on going, do all the work if you feel you need more send me an email and I can pick out a few more questions.

If you have noticed the work is organized by day in the calender, follow that and we should be on track. If you miss a day, make sure you catch up. I have left a couple of periods before the first test (in october - check calender) in case of early problems such as those experienced.

I am experiencing difficulty with web ct chat too. (as well as many other aspects)

With regards to the labs, if Mr Ingram is willing to take on that responsibility that would be fantastic. Tell him to drop me an email or call me if he is interested.

Lab number two is fairly safe and all that needs to be done is to prepared a few dilute solutions.

Keep in touch and if you have any questions regrading the course work post them to the web ct bulletin board so other people in the district can benefit from your questions.

You may want to print off the assignment to be due early in october (check calander)

Oh by the way labs and assignments are to be faxed to me at the school (talk to the secretary about this) D.C. fax number 468-1116.

Keep at it!

Mr. Wells

-----Original Message-----

From: jody spurrell <jodyspurrell@hotmail.com>  
To: bewells@calvin.sternnet.nf.ca <bewells@calvin.sternnet.nf.ca>  
Date: Monday, September 21, 1998 1:51 PM  
Subject: Chemistry 4222

>Mr. Wells,

>

> We went into the Chemistry program this morning during second period,  
>but the program wouldn't work. We got in as far as the chat home page  
>but that's it. We had the chemistry teacher in today, he checked to see  
>if there was anything he could help us with, but there wasn't very many  
>problems. We started lesson 5, and will have it completed for next  
>class. Now what about our labs, will we get the teacher here to help us  
>with them? Mr. Ingram has most of his prep. periods during the same time  
>as our scheduled classes. Please let me know.

>

Jody Spurrell

>

Bishop White

>

>

>Get Your Private, Free Email at <http://www.hotmail.com>

>

**From:** jody spurrell <jodyspurrell@hotmail.com>  
**To:** bewells@calvin.stemnet.nf.ca <bewells@calvin.stemnet.nf.ca>  
**Date:** Friday, September 25, 1998 1:20 PM  
**Subject:** Chem.4222

Mr. Wells,

I have started the assignment and I am not finding it too difficult yet. Mr. Ingram helped with what I didn't understand. We still haven't done the first lab, we were going to do it today but we don't have all the required equipment and one of the students(Jennifer Pond), is not here today. We will try to get it completed soon. I will Email you again if I come across any problems.

Jody Spurrell  
Bishop White

---

Get Your Private, Free Email at <http://www.hotmail.com>

**From:** Brian Wells <bewells@calvin.stemnet.nf.ca>  
**To:** Adam Butt <butt@m5817.direcpc.net>; angela kelley <kelley\_angela@hotmail.com>; Wilbert Boone <wboone@stemnet.nf.ca>; Natasha Avery <avery@m5817.direcpc.net>; jody spurrell <jodyspurrell@hotmail.com>; jennifer Hookey <jenniferhookey@hotmail.com>; Dave Power <dpower@calvin.stemnet.nf.ca>; brian <bewells@calvin.stemnet.nf.ca>; Derek Edge <council\_of\_wyrms@hotmail.com>  
**Cc:** jody spurrell <jodyspurrell@hotmail.com>; jennifer Hookey <jenniferhookey@hotmail.com>; Derek Edge <council\_of\_wyrms@hotmail.com>; brian <bewells@calvin.stemnet.nf.ca>; angela kelley <kelley\_angela@hotmail.com>; Adam Butt <butt@m5817.direcpc.net>; Natasha Avery <avery@m5817.direcpc.net>  
**Date:** Thursday, October 01, 1998 12:56 PM  
**Subject:** Help on question #57 p 182

Hi All!

Special request for question #57 pg 182.

In this question you are to identify the oxidized substance (the one that loses electrons) the reduced species( the one that gains electrons).

The reducing agent is the species that causes the reduction (or to put it another way the species tha gives up electrons -the one oxidized!)

The oxidizing agent is the species that cause the oxidation (or to put it another way the species that gains the electrons - the reduced one.)

In some cases a species may be both reduced and oxidized! (oxygen in 57 e) I'll do 58 c as an example.

I will do it in net meetingsd whiteboard. You have to save the attachment to this and go into netmeeting and use the whiteboard to view it. If there is anything you don't understand write it on the white image I send you and send it back via email as an attachment.

Let me know how this works

**From:** Derek Edge <council\_of\_wyrms@hotmail.com>  
**To:** bewells@calvin.stemnet.nf.ca <bewells@calvin.stemnet.nf.ca>  
**Date:** Friday, October 02, 1998 12:31 PM  
**Subject:** Question 57 f

Mr. Wells from what you showed me in 57 c and d i tried f and was  
wondering if it was correct!!!

---

Get Your Private, Free Email at <http://www.hotmail.com>

**From:** Brian Wells <bewells@calvin.stemnet.nf.ca>  
**To:** Natasha Avery <averyna@m5817.direpc.net>; jody spurrell <jodyspurrell@hotmail.com>; jennifer Hookey <jenniferhookey@hotmail.com>; Derek Edge <council\_of\_wyrms@hotmail.com>; brian <bewells@calvin.stemnet.nf.ca>; angela kelley <kelley\_angela@hotmail.com>; Adam Butt <butta@m5817.direpc.net>; kevin critch <kcritch@discovery.k12.nf.ca>; Brian Dalton <bdalton@discovery.k12..nf.ca>; Quentin Abbott <quentin.abbott.1@nf.sympatico.ca>  
**Date:** Friday, October 02, 1998 1:47 PM  
**Subject:** This is me!

---

Hi guys,  
this is a picture of me at work behind my computer.

If you have access to a digital camera or a scanner send me a mug of yourself.

Have a good weekend  
Mr. Wells

Picture Attachments:



File: me2 (1).bmp

**From:** Natasha Avery <averyna@m5817.direcpc.net>  
**To:** bewells@calvin.sternnet.nf.ca <bewells@calvin.sternnet.nf.ca>  
**Date:** Tuesday, October 06, 1998 10:28 AM  
**Subject:** chemistry

---

Mr. Wells,

Adam and I are seriously thinking about leaving Chemistry. We are still behind by nine lessons and catching up soon doesn't seem possible with an assignment due friday and a test the week after. We were wondering what you think. Please write us back soon!

Thanks,  
Natasha and Adam

**From:** Brian Wells <bewells@calvin.stemnet.nf.ca>  
**To:** Natasha Avery <averyna@m5817.direcpc.net>; jody spurrell <jodyspurrell@hotmail.com>; jennifer Hookey <jenniferhookey@hotmail.com>; Derek Edge <council\_of\_wyrms@hotmail.com>; brian <bewells@calvin.stemnet.nf.ca>; angela kelley <kelley\_angela@hotmail.com>; Adam Butt <butta@m5817.direcpc.net>; kevin critch <kcritch@discovery.k12.nf.ca>; Brian Dalton <bdalton@discovery.k12.nf.ca>; Quentin Abbott <quentin.abbott.1@nf.sympatico.ca>  
**Date:** Tuesday, October 06, 1998 10:20 AM  
**Subject:** re: Balancing redox

Hi,

I faxed out worked out solutions to balancing in redox. One for acidic conditions and the other for basic conditions.

Check with the secretary at the office to see if they arrived.

Work through them, try it on your own. Let me know how things go. These problems are all the same, once you get it down pat they're all the same. From then on its easy marks. Make surer you can do it. There will be one on your test and guaranteed there will be one on the ap final. Easy marks!

Get back to me if you still can't get it! Call me on the phone and I can talk you through it.

Mr Wells.

**From:** Derek Edge <council\_of\_wyrms@hotmail.com>  
**To:** bewells@calvin.stemnet.nf.ca <bewells@calvin.stemnet.nf.ca>  
**Date:** Tuesday, October 06, 1998 11:20 AM  
**Subject:** Re:

WhiteBoard is cool...it helps with since you can send me the information on how to solve a problem with out being here ro using a black board!!

---Original Message Follows---

**From:** "Brian Wells" <bewells@calvin.stemnet.nf.ca>  
**To:** "Derek Edge" <council\_of\_wyrms@hotmail.com>  
**Subject:**  
**Date:** Mon, 5 Oct 1998 19:13:38 -0230

Hi, Derek

What do you think of the whiteboard tool?

I have responded to your response.

Brian

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**From:** Brian Wells <bewells@calvin.stemnet.nf.ca>  
**To:** Quentin Abbott <quentin.abbott.1@nf.sympatico.ca>; Natasha Avery <averyna@m5817.direpc.net>; Kevin Critch <kcritch@discovery.k12.nf.ca>; jody spurrell <jodyspurrell@hotmail.com>; Jennifer Hookey <jenniferhookey@hotmail.com>; Derek Edge <council\_of\_wyrms@hotmail.com>; Brian Dalton <bdalton@discovery.k12.nf.ca>; brian <bewells@calvin.stemnet.nf.ca>; angela kelley <kelley\_angela@hotmail.com>; Adam Butt <butta@m5817.direpc.net>; Jennifer Pond <jenniferpond@hotmail.com>  
**Date:** Thursday, October 22, 1998 2:47 PM  
**Subject:** An extra lesson.

Greetings,

Its been a long week. After all week I finally have a network connection again. I thought it was gone forever!

I have somehow missed a lesson from the web pages. It took me all afternoon but it is finally up. You should see it as lesson 14-b on the calendar for Oct 23. It's a short lesson with only two questions. (sorry about that!)

I have now set up my sympatico account and will be available to conference on Monday, I guess. That will be first period Mon morning. I will get back to you if things change. Have your questions ready!!!

Mr Skiffington should have been to your school and set up the net-meeting program and modem. Check with your computer teacher!

The test has been corrected and is currently been sent back to you with an answer key.

The marks ranged a great deal but don't worry yet, It is still early. You all should be on lesson #15. Try not to fall behind!

Maybe we can talk about forgiving the first test if test two is better. (keyword is talk!) However you still need to know this stuff for the final!

Let me know what your net-meeting status is for Monday.

Don't forget have some questions for me (in advance please)

Mr. Wells







