Supporting Information for

Design, Evolution, and Evaluation of a General Chemistry Bridge Course

Table of Contents

Figure S1. Flyer for the bridge course.

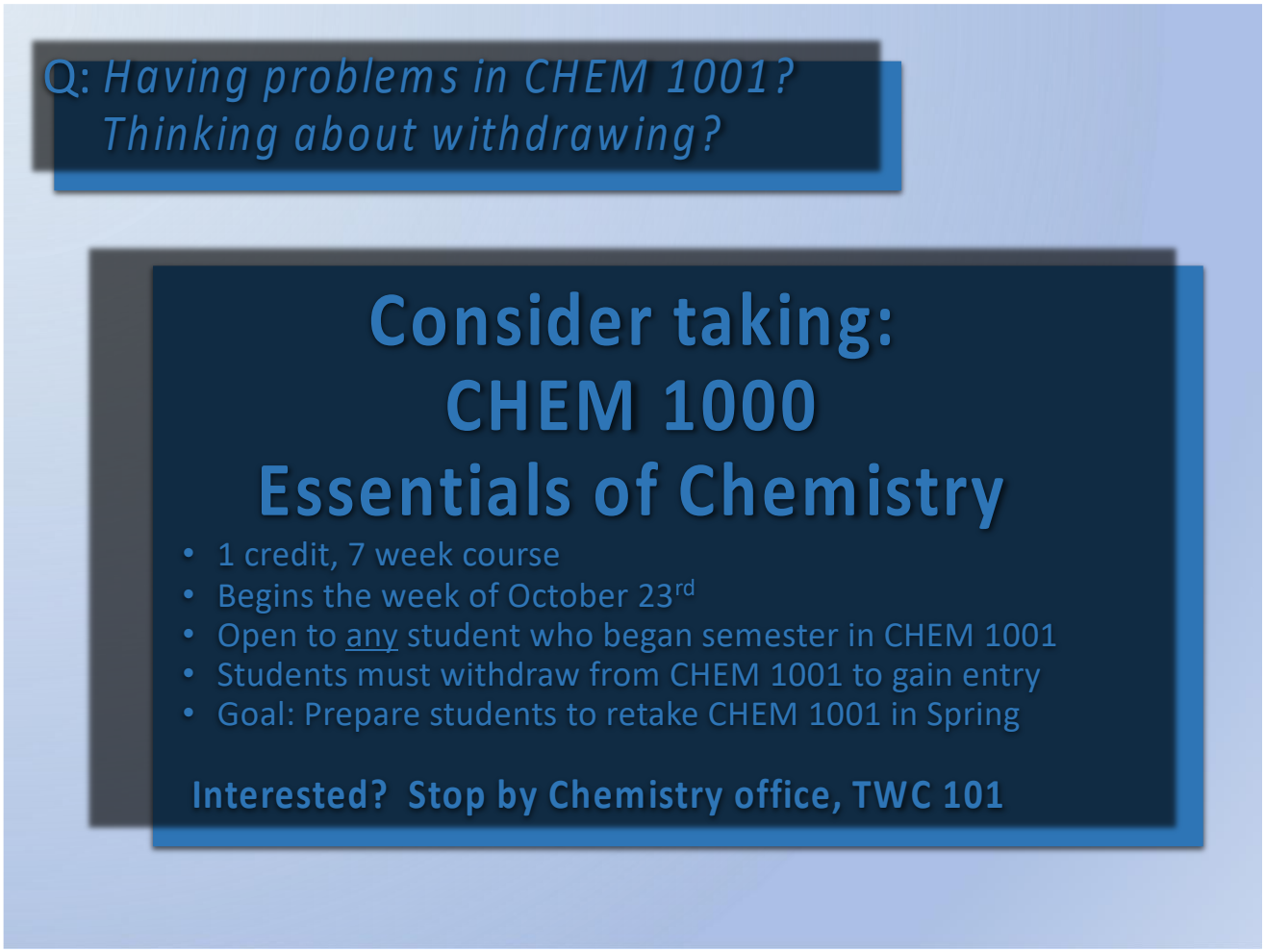


Table S1. Bridge course activities in the initial offering (F2016).

Week	Activities
1 Oct. 28	• Course Syllabus/Schedule • Scientific Reasoning and the Art of Deduction: Periodic Trends • Concept Mapping: Using the Concept Map in Chemistry
2 Nov. 4	• Asking Questions = Active Learning • Strategy for Formulating Good Questions • Expanding your Scientific Vocabulary • Microlecture: Formulating Questions
3 Nov. 11	• Dimensional Analysis • A Case Study in Dimensional Analysis: Taking Avogadro to Court • Microlecture: Formulating Questions
4 Nov. 18	• Thinking like a Chemist: What Element am I? • Microlecture: Formulating Questions
5 Nov. 25	CLASS DOES NOT MEET: Thanksgiving Break
6 Dec. 1	• A Case Study: Chemical Bonding • Microlecture: Formulating Questions
7 Dec. 9	• Limitations in Chemistry: The Limiting Reagent • An exercise in note-taking

Table S2. Bridge course activities in the F2018 offering.

Week	Activities
1 Oct. 26	• Course Syllabus/Schedule • Electron Configuration and the Structure of the Atom • Concept Mapping: Using the Concept Map in Chemistry
2 Nov. 2	• Thinking like a Chemist: What Element am I? • Scientific Reasoning and the Art of Deduction: Periodic Trends
3 Nov. 9	• Dimensional Analysis and Problem Solving in Chemistry • A Case Study in Dimensional Analysis: Taking Avogadro to Court
4 Nov. 16	• Bonding over Questions: Chemical Bonding • Asking Questions = Active Learning
5 Nov. 23	CLASS DOES NOT MEET: Thanksgiving Break
6 Nov. 30	• Sticking Together in Chemistry • Electronegativity and Intermolecular Forces
7 Dec. 7	• Limitations in Chemistry: What is a Limiting Reagent? • Taking Notes

Table S3. Assignment schedule for the online bridge course.

Week Module	Assignment Title	Assignment Type	Day	Due Dates
0 Preparation	Register for Bubbl	Website	Tuesday	12/15
0 Preparation	Time Management	Dropbox	Monday	12/14
0 Preparation	Set your Notifications in D2L	D2L Profile	Before Course Work	NA
0 Preparation	Introductions	Discussion	Monday	12/14
1 Air We Breathe	1.1 Lecture Notes	Dropbox	Wednesday	12/16
1 Air We Breathe	1.2 Mind Map	Discussion	Wednesday Sunday	12/16 12/20
1 Air We Breathe	1.3 Case Study	Dropbox	Sunday	12/20
1 Air We Breathe	1.4 Quiz	Quiz	Sunday	12/20
2 Elements and Earth	2.1 Lecture Notes	Dropbox	Sunday	12/27
2 Elements and Earth	2.2 Mind Map	Discussion	Sunday Sunday	12/27 1/3
2 Elements and Earth	2.3 Case Study	Dropbox	Sunday	1/3
2 Elements and Earth	2.4 Quiz	Quiz	Sunday	1/3
3 Fire and Flame	3.1 Lecture Notes	Dropbox	Sunday	1/10
3 Fire and Flame	3.2 Mind Map	Discussion	Sunday Sunday	1/10 1/17
3 Fire and Flame	3.3 Quiz	Quiz	Sunday	1/17
4 Water: Solvent of Life	4.1 Lecture Notes	Dropbox	Wednesday	1/20
4 Water: Solvent of Life	4.2 Mind Map	Discussion	Wednesday Sunday	1/20 1/24
4 Water: Solvent of Life	4.3 Quiz	Quiz	Sunday	1/24

Example Activities

CHEM 1000 Week 1

- Activities for Week 1:
  - ✓ *Developing a Concept Map of Electron Configuration*
  - ✓ *Understanding Periodic Trends*
    - ✓ *Atomic Radius*
    - ✓ *Ionization energy*
    - ✓ *Electron Affinity*

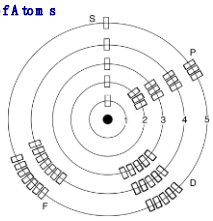
CHEM 1000 Week 1

1

Concept Map of Electron Configuration

- Central concept:

  Electron Configuration of Atoms
- Associated Concepts…
  - ✓
  - ✓
  - ✓
  - ✓
  - ✓
  - ✓
  - ✓
  - ✓



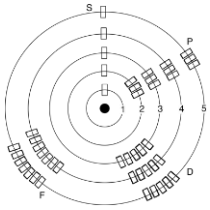
STOP! Try this before proceeding

2

Concept Map of Electron Configuration

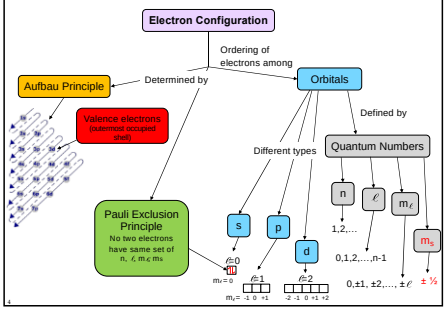
- Central concept:

  Electron Configuration
- Associated Concepts…
  - ✓ Quantum numbers
  - ✓ n, l, m_l, m_s
  - ✓ Orbitals
  - ✓ s, p, d, … types of orbitals
  - ✓ Pauli Exclusion Principle
  - ✓ Aufbau principle
  - ✓ Valence electrons



3

Concept Map of Electron Configuration



4

CHEM 1000 Week 2

- Activities for Week 2:
  - ✓ *What Element am I?*
  - ✓ *Understanding Periodic Trends*

1

What Element am I?

- This activity focuses on identifying elements in the periodic table from their key properties…
- I will give clues one by one
- For each clue, provide a statement of conclusion or reasoning – ie., what information can you draw from that clue?
- The point is to try and identify each element using the minimum number of clues
- Let's get started…

2

Element 1

Clue 1: I am a non-metal.

Clue 2: I belong to the Halogen family.

Clue 3: I am not the largest nor smallest atom in my group.

Clue 4: My first ionization energy is greater than that of my group member Iodine.

Clue 5: At room temperature I am not a gas.

What element am I?

3

Element 1 is… Bromine!

- Bromine is a chemical element with symbol Br and atomic number 35. It is the third-lightest halogen, and is a fuming red-brown liquid at room temperature that evaporates readily to form a similarly coloured gas.
- Symbol: Br
- Electron configuration: $[Ar]3d^{10}4s^24p^5$
- Atomic number: 35
- Atomic mass: 79.904 u ± 0.001 u
- Electronegativity: 2.96
- Melting point: 19.04° F (-7.2° C)
- Boiling point: 137.8° F 68.8° C)

4

Element 2

Clue 1: I am a metal.

Clue 2: I am a transition metal.

Clue 3: I have the smallest atomic radius in my group.

Clue 4: I have 6 valence electrons

What element am I?

5

Element 2 is… Chromium!

- Chromium is a chemical element with symbol Cr and atomic number 24. It is the first element in Group 6. It is a steely-grey, lustrous, hard and brittle metal which takes a high polish, resists tarnishing, and has a high melting point.
- Symbol: Cr
- Electron configuration: $[Ar]3d^54s^1$
- Atomic number: 24
- Atomic mass: 51.9961 u ± 0.0006 u
- Discovered: 1797
- Melting point: 3,465° F (1,907° C)

6

CHEM 1000 Week 3: Dissecting Dimensional Analysis

- Questions and issues to be addressed:
  - ✓ *Dimensional Analysis: Following the Units*
  - ✓ *A case study: Taking Avogadro to Court*

1

Taking Avogadro to Court… A Case Study

- Based on assignment a Professor gave to introductory computer class
- Assignment was to determine the cost of a single aluminum atom in a roll of aluminum foil…
- … given the following information
  - Cost and size of the roll
  - Atomic mass of aluminum
  - Avogadro's number
- The assignment led to a revolt, and two students actually sued for a refund of their tuition
- Let's explore the case and assignment….

2

The assignment

- Using dimensional analysis, determine the cost of a single aluminum atom in a roll of aluminum foil…
- … given the following information
  - Cost and size of the roll
  - Physical properties of aluminum
  - Avogadro's number
- You can make measurements as you see fit!
- Let's get started….

3

Step 1: Set up your starting point

- Determine the cost of a single aluminum atom in a roll of aluminum foil given the following information
  - Cost and size of the roll
    - $24.49 for roll of size 12" x 500'
  - Physical properties of aluminum
    - Atomic mass = 26.98 g/mol
  - Avogadro's number
    - NA = 6.022 x 10^{23} atoms/mol

$$\frac{\$24.49}{1 \text{ roll}}$$

4

Step 2: Set up your ending point

- Determine the cost of a single aluminum atom in a roll of aluminum foil given the following information
  - Cost and size of the roll
    - $24.49 for roll of size 12" x 500'
  - Physical properties of aluminum
    - Atomic mass = 26.98 g/mol
  - Avogadro's number
    - NA = 6.022 x 10^{23} atoms/mol

$$\frac{\$24.49}{1 \text{ roll Al}} \qquad \frac{\$0.XXX}{1 \text{ atom}}$$

5

Step 3: Set up your conversions

- Determine the cost of a single aluminum atom in a roll of aluminum foil given the following information
  - Cost and size of the roll
    - $24.49 for roll of size 12" x 500'
  - Physical properties of aluminum
    - Atomic mass = 26.98 g/mol
  - Avogadro's number
    - NA = 6.022 x 10^{23} atoms/mol

$$\frac{\$24.49}{1 \text{ roll Al}} \qquad \frac{\$0.XXX}{1 \text{ atom}}$$

Ideas?

6

CHEM 1000 Week 4: Bonding Over Questions

- Questions and issues to be addressed:
  - ✓ *Your Questions about Chemical Bonding*
  - ✓ *A case study in Chemical Bonding*

1

A Sampling of your questions

- Questions from you:
  - ✓ *Understanding noble gases are stable what makes the valence electrons so attracted?*
  - ✓ *How does electronegativity work?*
  - ✓ *Why do ionic compounds form crystal lattices?*
  - ✓ *How do you know when to remove and add electrons from looking at the periodic table?*
  - ✓ *How can you tell which atoms have higher bond energies than others?*
  - ✓ *What is a better way to understand the Coulomb's law equation?*

2

A Sampling of your questions

- Questions from you:
  - ✓ *Why are polar covalent bonds not equal?*
  - ✓ *When I think of polar covalent bonds I think of water but water mixes with water.*
  - ✓ *When do you use lewis structures when figuring out an answer?*
  - ✓ *How does the octet rule work?*

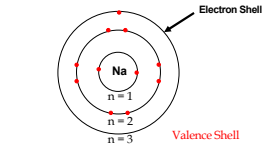
3

4

Slides for Part 1 of Case Study

5

Electron Shells



6

CHEM 1000 Week 5: Sticking Together in Chemistry

- Questions and issues to be addressed:
  - ✓ *Intermolecular Forces*
  - ✓ *Like dissolves like: explaining solubility*
  - ✓ *A case study: Decaffeinating Coffee*
  - ✓ *Weak, but important! Intermolecular Forces in Proteins*
  - ✓ *Q and A time*

1

Solutions: Nomenclature

- **Solute**: Component of solution that is present in smallest number of moles
- **Solvent**: Component of solution that is present in largest number of moles
- **Solubility**: Maximum quantity of substance that can dissolve in a given volume of solution
- **Miscible**: Liquids that are mutually soluble in any proportion

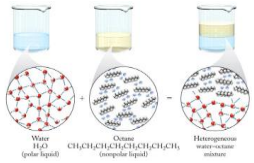
2

Solubility

- Solubility depends on relative strength of solute–solvent interactions compared to solute–solute or solvent–solvent.
- **Like Dissolves Like**:
  - Ionic/polar solutes will be soluble in polar solvents.
  - Nonpolar solutes will be soluble in nonpolar solvents.

3

Like Dissolves Like



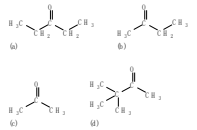
Dissimilar forces = No solution!

4

Check-in Question 1

Which of the following is the most soluble in water?

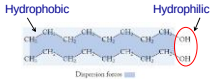
(a)
(b)
(c)
(d)



5

Hydrophobic vs. Hydrophilic

- Some molecules contain both a polar group and non-polar group
- **Hydrophobic** ("water-fearing")
  - interaction that repels water, diminishes water solubility.
- **Hydrophilic** ("water-loving")
  - interaction that attracts water, promotes water solubility.



6

CHEM 1000 Week 6

- Questions and issues to be addressed:
  - ✓ *Note-taking strategies in science (and other) classes*
  - ✓ *Note-taking practice: Chemical Reaction Equations and Stoichiometry*
  - ✓ *Limitations in Chemistry: The Limiting Reagent*
  - ✓ *A Case Study in Limiting Reagent*

1

Tips for *Effective* Listening

- ✓ Sit near the front of the room. Pay attention. Avoid outside distractions and internal noise. Be **focused** rather than **distracted**.
- ✓ Find a reason to listen to the speaker. Ask yourself, "Why is this important?" Be a **willing**, not **reluctant** listener.
- ✓ Listen for more than just facts; try to understand the big picture. Select main ideas. Be **engaged**, not **unengaged**.
- ✓ Anticipate what the speaker is going to say next. Be an **active**, not **passive** listener.
- ✓ Listen first, then write; leave spaces to fill in gaps in your information.
- ✓ **Formulate questions** to ask the instructor, in class or in office hours later. Participate.

2

Write it down if the speaker...

- Repeats an item.
- Writes an item on the board or overheads.
- Points or gestures.
- Changes tone or volume of voice.
- Makes a direct reference to the book or external reference.
- Asks if everyone understands. **If you don't understand, ask a question!**
- Gives an example.
- Changes pace (e.g., slows down).

3

Note-taking: A checklist

- ➢ **List and look up** unfamiliar terms and concepts.
- ➢ **List questions** to ask or points where clarification is needed.
- ➢ **Abbreviate.** Put notes into my own words. Keep the notes brief.
- ➢ **Number items** and distinguish between major/minor points.
- ➢ **Look/listen for word clues** and other ways important concepts are highlighted.
- ➢ **Review lecture notes** within twenty-four hours.

4

Note-taking: Cornell Method

- Main Idea
- Central Questions

(after notes are completed)

- Key Vocabulary
- Terms to look up

- Key ideas/concepts/questions
- Important dates/events/people
- Repeated/stressed information
- Ideas/brainstorming, writing on board
- Information from textbook or other sources
- Important formulas
- Diagrams and pictures

- Summary of your notes in your own words

5

Note-taking with PPT slides

- If ppts are distributed before class, print them in notes form
- Use this to identify key questions and concepts
- Let's try this!

6

Module Content Worksheet – CHEM 1000 M1

MODULE TITLE

The Air that we Breathe

MODULE OVERVIEW

All living beings have a mechanism for taking and using chemicals from the air – usually for the process of respiration and generation of energy. Thus, every minute of every day our lungs are taking in and breathing out gases.

Have you ever considered what gases you're breathing in and exhaling out? Beyond nitrogen and oxygen, what is the chemical composition of air? What do we mean by "good" air or "bad" air? How do chemists measure and quantify the amount of toxins in our air?

In this module, we will use the lens of air quality to examine fundamental chemical concepts about the nature of matter and chemical measurement.

We will be able to describe the chemical and physical properties of air, and examine how scientists might define and determine the composition of air. In the process, we will learn how to make and report scientific measurements, distinguishing accuracy and precision. We will explore units of concentration, and perform calculations using unit or dimensional analysis, which is a mathematical tool used throughout chemistry.

This module will be completed in the first week of the course, broken down as follows. In the first part of the week, you will view short video lectures on the topics, and take notes. You will submit those notes by Wednesday evening. In the later part of the week, you will complete homework, concept map, and case study assignments related to the lecture content. Detailed descriptions on the completion and grading of each assignment are included.

LEARNING OUTCOMES for Module

- **Classify types of matter, distinguishing between mixtures and pure substances**
- **Distinguish between physical and chemical properties**
- **Demonstrate use of dimensional analysis to solve problems**
- **Use developed guidelines to determine significant figures in numerical measurements, and in calculations**
- **Differentiate between accuracy and precision in measurement**
- **Classify the different units of concentration, and use unit analysis to convert between them**

List REQUIRED RESOURCES Readings, Lectures, Web Sites,Videos, or Other Sources of Content

- Lectures 1.1 and 1.2
- Case Study: Avogadro Goes to Court

GRADED ASSIGNMENTS

Graded Assignment 1:
Submit Notes from Lectures
Graded on S/U basis using Note-taking Rubric
8 points
Due Wednesday of Week 1

Graded Assignment 2:
Submit Completed Concept Map for Module 1 and Complete Online Discussion
Graded on S/U basis
4 points (3 points initial post, 1 point discussion)
Due at end of Week 1

Graded Assignment 3:
Complete Module 1 Quiz
10 points
Due at end of Week 1

Graded Assignment 4:
Case Study Assignment
8 points
Due at end of Week 1

Total for Week 1: 30 points

Module Content Worksheet – CHEM 1000 M2

MODULE TITLE

Of Elements and Earth

MODULE OVERVIEW

Matter is all around us, in the air we breathe, food we eat, products that we use every day. But what comprises matter? In this module, we will examine atoms, the most fundamental chemical building blocks in nature, and see how these can be combined to make molecules and larger structures such as polymers and plastics.

Using the periodic table as our guide, will examine the sizes and structure of atoms, classify atoms as either metals or non-metals, and distinguish the various types of bonding interactions which connect atoms into larger networks. We will learn how we can represent molecules using Lewis structures, and go from Lewis structures to the 3-dimensional shape of molecules, which is critical for determining the physical and chemical properties of matter.

LEARNING OUTCOMES for Module

- Discuss periodic trends in properties among the main group elements and their ions using trends in atomic radii, ionization energy, and electron affinity
- Differentiate between ionic, covalent and metallic bonding, comparing and contrasting properties of each
- Compare and contrast properties of metals and non-metals
- Use Lewis structures and Valence Shell Electron Pair repulsion theory to describe the bonding and three-dimensional structure of molecules. Describe periodic trends in ionization energy and electron affinity

REQUIRED RESOURCES Readings, Lectures, Web Sites, Videos, or Other Sources of Content

- Lectures 2.1, 2.2, 2.3
- Case Study: Chemical Bonding

GRADED ASSIGNMENTS

Graded Assignment 1:
Submit Notes from Lectures 2.1-2.3
Graded on S/U basis using Note-taking Rubric
4 points
Due at end of Week 2

Graded Assignment 2:
Submit a Concept Map for Module 2 on either of the following:
Periodic Trends for Atoms/Ions or Chemical Bonding
Graded on S/U basis
4 points
Due at end of Week 2

Graded Assignment 3:
Complete Module 2 Problems
10 points
Due at end of Week 2

Graded Assignment 4:
Post 2 questions/responses to discussion board
2 points
Due at end of Week 2

Graded Assignment 5:
Case Study Assignment
10 points
Due at end of Week 2

Total for Week 1: 25 points

Module Content Worksheet – CHEM 1000 M3

MODULE TITLE

Of Fire and Flame

MODULE OVERVIEW

Sitting by the campfire on a brisk fall night – that's an activity that anyone can enjoy! Staring into the fire as the logs are consumed, did you ever wonder what chemistry is taking place?

The burning of wood is an example of a **chemical reaction**, where chemical bonds are broken and new ones formed, but the number and type of the atomic building blocks that make up the molecules is conserved. This specific reaction is called a **combustion reaction**, which involves a fuel (such as the wood) reacting with oxygen in the air to make carbon dioxide and water. Combustion reactions generate (or release) energy, and thus are very important types of reactions in our society. We call such reactions **exothermic**.

In this module, we will examine chemical reactions from the viewpoint of combustion. We will learn how to write balanced reaction equations, using combustion reactions as our guide, and determine the limiting reagent in cases where the one reagent is present in excess over another. We will then examine the energy changes in chemical reactions, differentiating between endothermic and exothermic reactions, and examine ways to calculate the energy absorbed or released in chemical reactions.

LEARNING OUTCOMES for Module

- Write and balance equations for simple chemical reactions, including the physical state of reactant and product
- Differentiate endothermic and exothermic processes, connecting to the first law of thermodynamics
- Define enthalpy, discuss why it is a useful variable for heat transferred in reaction
- Calculate enthalpy changes for reactions using different approaches

REQUIRED RESOURCES Readings, Lectures, Web Sites, Videos, or Other Sources of Content

- Lectures 3.1, 3.2, 3.3

GRADED ASSIGNMENTS

Graded Assignment 1:

Submit Notes from Lectures
Graded on S/U basis using Note-taking Rubric
8 points
Due Wednesday of Week 1

Graded Assignment 2:
Submit Completed Concept Maps for Module 3 and Complete Online Discussion
Graded on S/U basis
8 points (6 points initial posts, 2 point discussion)
Due at end of Week 1

Graded Assignment 3:
Complete Module 3 Quiz
10 points
Due at end of Week 1

Total for Week 1: 26 points

Module Content Worksheet – CHEM 1000 M4

MODULE TITLE

Water is the Solvent of Life

MODULE OVERVIEW

Here in the US, we don't think too much about our daily water supply and needs, as nearly 100% of folks in our country have access to clean, safe drinking water. However, this isn't true across the world.

According to the United Nations, 844 million people around the world still lack even basic access to safe drinking water! Unsafe water can lead to diseases like cholera, typhoid and hepatitis A, and, according to the Emergency Event Database and the Netherlands Environmental Assessment Agency, is a bigger cause of human death annually than all disasters and conflict combined. Infants and children are particularly affected.

Water is indeed important, and from a chemical perspective can be considered as the solvent of life. In chemistry, a solvent is a substance which facilitates a chemical reaction by providing a platform for reagents to interact. Water is a critical solvent.

In this module, we will examine the physical properties of water which make it such an important solvent. We will learn that water is polar, and thus can easily solvate polar molecules and ions. We will then examine the properties of aqueous solutions, and examine units of concentration. Closing the module, we will examine important types of reactions which take place in water, along with methods of chemical analysis.

LEARNING OUTCOMES for Module

- Define intermolecular forces, and connect molecular structure and polarity to types of intermolecular forces
- Describe the uniqueness of the phase diagram for water and connect to the physical and chemical properties of water
- Discuss properties of aqueous solutions and measures of concentration
- Identify important reactions occurring in aqueous solution and methods for chemical analysis

REQUIRED RESOURCES Readings, Lectures, Web Sites, Videos, or Other Sources of Content

- Lectures 4.1, 4.2, 4.3

GRADED ASSIGNMENTS

Graded Assignment 1:
Submit Notes from Lectures
Graded on S/U basis using Note-taking Rubric
8 points
Due Wednesday of Week 4

Graded Assignment 2:
Submit Completed Concept Maps for Module 3 and Complete Online Discussion
Graded on S/U basis
8 points (6 points initial posts, 2 point discussion)
Due at end of Week 4

Graded Assignment 3:
Complete Module 4 Quiz
10 points
Due at end of Week 4

Total for Week 4: 26 points