אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

Chemistry of Water Sylabuss

COURSE DETAILS

Course Name	Chemistry of Water	**Course Number**	001-2-0003
Department/School	Albert Katz International School for Desert Studies	**Campus**	Sde Boker
Semester	Spring	**Degree Level**	Graduate (MSc and PhD)
Credit Points	3	**Language**	English
Instruction	Frontal (In-person)	**Structure**	Lecture (3 hours)

Course Description and Goals

This course is designed to equip students with the essential theoretical background, practical understanding, and computational tools necessary for solving problems in water chemistry. The focus spans both natural water systems and critical water treatment processes, including desalination, softening, mineralization, and wastewater purification. The primary focus is on chemical equilibrium phenomena occurring in the aqueous phase and at the interfaces with the gaseous and solid phases. A special emphasis is placed on Acid-Base Chemistry, specifically the carbonic system, which acts as a dominant pH buffer across various environmental compartments (aqueous, atmosphere, lithosphere, and anthroposphere. The course also covers oxidation-reduction processes, which are mostly irreversible reactions that significantly interact with equilibrium systems. The course will continuously demonstrate the relevance of these concepts to real-world applications in physico-chemical and biological water treatment technologies and water resource management.

LEARNING OUTCOMES

Upon successful completion of the course, students will be able to:

1. **Activity & Equilibrium:** Explain the concept of activity and calculate the influence of salinity and temperature on equilibrium constants in non-ideal aqueous solutions.
2. **Acid-Base Fundamentals:** Explain foundational acid-base chemistry concepts relevant to environmental engineering, such as pH, alkalinity, and acidity, with a focus on the carbonic system.
3. **Aqueous Phase Quantification:** Utilize alkalinity and acidity terms to assess acid-base equilibrium processes in the aqueous phase quantitatively.
4. **Gas-Liquid Equilibrium:** Quantify gas-liquid equilibrium processes (e.g., Henry's Law) and integrate them with acid-base equilibrium in multi-phase systems.
5. **Solid-Liquid Equilibrium:** Quantify solid-liquid equilibrium processes (solubility and precipitation) and integrate them with gas and aqueous phase reactions.
6. **Redox and Integration:** Balance fundamental oxidation-reduction equations and integrate them with aqueous, gaseous, and solid-phase equilibrium processes to solve complex problems.

Course Content

Topic Name	Topic Description	Resources
1. Solutions and Equilibrium	Review of aqueous solutions, electrolytes, chemical equilibrium, acids/bases, and environmental concentration units. Calculation of activity coefficients and equilibrium constants in non-ideal solutions based on temperature and ionic strength.	Course textbook – All of Chapter 1
2. Acids, Bases, and the Carbonic System	Review of acid/base definitions, strong/weak acids, polyprotic acids, and the Henderson-Hasselbalch equation. Detailed study of the Carbonic System, including speciation distribution and the proton balance equation.	Course textbook – Chapter 2 (2.1-2.7, 2.9-2.10)
3. Proton Balance and Equivalence Points	Problem-solving techniques using the proton balance equation for the addition of various acids/bases. Definition and examples of equivalence points, particularly for the carbonic system.	Course textbook – Chapter 2 (2.10-2.11), Tutorial presentation
4. Alkalinity and Acidity	Definitions of alkalinity and acidity, mathematical derivation, and relationships between different values. Laboratory measurement of alkalinity (titration to pH=4.5).	Course textbook – Chapter 3 (All except 3.12)
5. Applied Acid-Base Problem Solving	Solving advanced acid-base equilibrium problems: stream mixing scenarios and chemical addition examples relevant to environmental engineering.	Course textbook – All of Chapter 4
6. Gas-Liquid Equilibrium	Henry's Law, open vs. closed systems. Equilibrium with CO2 (integration with the carbonic system) and other acid-base systems.	Course textbook – All of Chapter 5

7. Solid-Liquid Equilibrium	Solubility and precipitation, degree of saturation, and the effect of ionic strength/temperature in non-ideal solutions. Calculation of precipitation/dissolution with and without side reactions.	Course textbook – Chapter 6 (6.1–6.5, 6.6.2-6.6.3), Presentation
8. Multi-Phase Systems and PHREEQC	Introduction to the PHREEQC geochemical modeling software. Problem-solving in aqueous solutions: speciation as a function of pH, mixing, and chemical addition simulations.	Software website [3], Presentation, Input files
9. PHREEQC as a Design Tool	Introduction to designing water treatment processes using PHREEQC. Focus on water softening and water stabilization processes.	Software website [3], Input files
10. Introduction to Redox in Environmental Engineering	Importance of redox reactions. Comparison with acid-base equilibrium. **Half-reaction method** for balancing equations. Problem-solving combining redox and equilibrium processes.	Additional Course materials
11. Integrating Kinetics with PHREEQC	PHREEQC simulation of time-dependent oxidation-reduction reactions, combined with chemical equilibrium side reactions (kinetics integration).	Software website [3], Input files

Assesment and Grading*

Criterion	Weight (%)	Notes
Final Exam	70%	Includes one open question and a multiple-choice section.
In-class Presentation	20%	A competitive assignment resulting in a relative grade.
Attendance	10%	A maximum of two unjustified absences is permitted.

***התאמות עבור סטודנטים המשרתים במילואים יבוצעו באופן פרטני**

Resources (Numbererd for references in the text)

1. Lahav, O.; Birnhack, L. Aquatic Chemistry: For Water and Wastewater Treatment Applications; de Gruyter: Boston, MA, 2019.
2. Aquatic Chemistry 3rd edition, Werner Stumm and James J. Morgan .
3. https://www.usgs.gov/software/phreeqc-version-3