SAGRADO
Universidad del Sagrado Corazón

SCHOOL OF HEALTH AND SCIENCES

SYLLABUS

TITLE:	Analytical Chemistry: Quantitative Analysis
CODE:	QUI 205
PREREQUISITE:	QUI 102
CORREQUISITES:	QUI 205L
CREDITS:	4 credits | 45 contact hours | 75 lab hours | 1 term

DESCRIPTION

Course aimed at students majoring in Chemistry. Introduction to the study of classical methods of chemical analysis, chemical equilibrium in aqueous solutions, statistical analysis of data obtained from a chemical analysis. Study of the theory of gravimetric and volumetric methods, acid-base equilibria, complexation, oxy-reduction and precipitation, analytical separations and basic principles of analytical instruments and their applications. The course incorporates laboratory experiences to apply theoretical knowledge by performing a reliable quantitative chemical analysis. The course is developed through lecture, laboratories, simulations, incorporation of technology supported by the web, writing and defense of a bibliographic research proposal, and ethical aspects related to the management of data in the laboratory and report of results of a chemical analysis.

JUSTIFICATION

The development of modern science increasingly interrelates with the different areas of knowledge. The complete mastery of chemical analysis methods, as well as the acquisition of the typical operational techniques to carry out such analyses, are essential for the proper characterization of a chemical system. In all areas of science, some analysis has to be carried out, such as the determination of heavy metals in biological, environmental, or industrial matrices. Such analyses are carried out, for example, to determine the potency of a medicine, the content of a regulated compound in drinking water, or the concentration of a component in a sample of biological origin. The results obtained are subjected to statistical treatment in such a way that a result can be reported with a certain degree of reliability. In private research labs and academic institutions, scientists submit research proposals to organizations such as the National Science

Foundation (NSF) in order to receive funding to conduct research. Therefore, a student who aspires to have a Chemistry major must have a basic knowledge of analytical methods and the theory behind those methods to be able to submit a research proposal. This course's contribution to students' profiles is that they acquire the necessary skills to perform a chemical analysis. Students also learn how to write a report while maintaining an ethical commitment to the integrity of the analysis performed and the result obtained.

COMPETENCES

The course develops the following competences in students:

- **Critical questioning**
- **Research and exploration**

OBJECTIVES

After completion of the course, students will be able to:

1. Carry out a chemical analysis by critically examining each of its stages and the problems related to them.
2. Analyze the experimental results of an analytical chemical procedure by means of statistics.
3. Explain the fundamentals of theory related to classical methods of chemical analysis.
4. Explain the fundamentals of theory related to instrumental chemical analysis methods.

CONTENTS

I. Basic Concepts of Analytical Chemistry
   A. Steps of a chemical analysis
      1. Method selection
      2. Sampling
      3. Sample preparation
      4. Definition of replicated samples
      5. Sample dissolution
      6. Elimination of interference
      7. Measurement of analyte property
      8. Computations and statistical analysis
      9. Interpretation of the results

B. Solutions
    1. Molarity
    2. Percent by weight, weight by volume, and volume by volume
    3. Parts per million, per billion, and per trillion
    4. The p-function
    5. Ionic strength and activity coefficient
    6. Activity
C. The equilibrium state
    1. The equilibrium constant
    2. Acid-base balance
        a. pH
        b. Ka
        c. Kb
    3. Precipitation equilibrium
        a. Solubility rules
        b. Kps
        c. Common ion effect
    4. Complexation equilibrium
        a. Complex ions
        b. Formation constant
        c. Values of β
    5. Redox equilibrium
        a. Redox reaction
        b. Oxidizing and reducing agents
        c. Balancing of Redox reactions in acid and basic mediums
    6. Partition equilibrium
        a. Liquid-liquid extraction
        b. Kd

II. Statistical Evaluation of a Chemical Analysis
A. Measurements and their errors
    1. Determined errors
    2. Indeterminate errors
B. Normal distribution curve

1. Curve shape
2. Properties

C. Data management
1. Average
2. Standard deviation
3. Q-test
4. T-test
5. F-test

III. Classic Methods of Chemical Analysis

A. Gravimetric analysis
1. Gravimetric Chemical Factor
2. Properties of precipitates
    a. Relative supersaturation
    b. Precipitate size
3. Thermogravimetry

B. Volumetric analysis
1. General considerations
    a. Analyte
    b. Titration
    c. Standard solution
    d. Primary type and its properties
    e. Process of a titration
    f. Feasible titration
    g. Mathematical treatment of experimental data
    h. Equivalence point and endpoint
    i. Back-titration
2. Acid-base titrations
    a. pH of a strong acid or base solution
    b. pH of a weak monoprotic acid or base solution
    c. pH of a salt solution whose anion is a weak acid conjugate base or whose cation is weak base conjugated acid
    d. pH of a polyprotic acid solution
    e. pH of a salt possessing an amphoteric species

f. pH of a buffer system
g. Acid-base titration curves
    1) Strong with strong
    2) Weak with Strong
    3) Phosphoric acid with strong base
    4) Sulfuric acid with strong base
    5) Diprotic acid with strong base
    6) Sodium carbonate with strong acid
    7) Sodium bicarbonate with strong acid
    8) Acid mixtures with strong base
    9) Base mixtures with strong acid
h. αn values for a weak acid of type HnX
i. I. Acid-base indicator turning zone

3. Complexometric titrations
    a. Complex ion
        1) Metal cation
        2) Ligand
        3) Coordination number
        4) Metal cation hybridization
    b. Chelated complexes
    c. EDTA
        1) Structure
        2) α vs pH values
    d. Conditional training constant
    e. Titration curve with EDTA
    f. Indicators used

IV. Fundamentals Of Instrumental Chemical Analysis
    A. Purpose of the instrumental chemical analysis
    B. Components of an analytical instrument
    C. Classification of instrumental methods
    D. Calibration curves
        1. External calibration
        2. Standard addition

3. Internal standard
4. Analytical sensitivity

E. Linear regression

F. Noise
    1. Definition
    2. Types of noise
    3. The signal-to-noise ratio
    4. C_M limit of detection
        a. Blank signal
        b. Determination of C_M

G. Electrochemistry
    1. Components of a galvanic cell
        a. Electrodes
        b. Salt bridge
        c. Voltmeter
        d. Current passage
        e. Polarity
        f. Cell potential
        g. Galvanic and electrolytic cell
    2. The standard potential
        a. Definition
        b. Normal Hydrogen electrode
        c. Determination of E^o
        d. Activity series
    3. Nernst's equation
        a. Variables in that equation
        b. Computation of electron potential
    4. Computation of the equilibrium constant of a redox reaction via E^o
    5. Reference electrodes
        a. Saturated calomel electrode
        b. Ag/AgCl electrode
    6. Use of galvanic cells to determine Ka, Kf, and Kps.
    7. Types of electrodes

        a. Electrode of the first kind
        b. Electrode of the second kind
        c. Redox electrode
    8. Redox titration curves
        a. Instrumental apparatus
        b. Potential before and after the equivalence point
        c. Potential at the point of equivalence
        d. Indicator turning zone

H. Molecular spectroscopy
    1. Electromagnetic radiation
    2. Electronic transitions
    3. Transmittance and absorbency
    4. The Beer-Lambert Law and Its deviations
    5. Instrumentation
        a. Radiation sources
        b. Types of cells
        c. Monochromators and filters
        d. Detectors

I. Non-chromatographic analytical separations
    1. Solid phase extraction and microextraction
        a. Theoretical foundations
        b. Applications
    2. Chromatography
        a. Introduction
        b. Intermolecular interactions
        c. Types of chromatography
        d. Mobile phase, stationary phase, and packing
        e. Retention time
        f. Theoretical plates
        g. Van Deemter equation
    3. High performance liquid chromatography (HPLC)
        a. Solvents
        b. Pressure pumps

c. Sample injection systems
d. Columns
e. UV detector
f. Applications

LAB EXPERIENCES

A. Introduction to the Analytical Chemistry Laboratory
B. Statistics in a chemical analysis
C. Assessment of a NaOH solution with KHP
D. Determination of water hardness by ion exchange
E. Titration of $AgNO_3$ solution by the Fajans' method
F. Determination of soda ash
G. Determination of hypochlorite in *Clorox*
H. Potentiometric determination of phosphate mixture
I. Titration of EDTA solution with primary type $CaCO_3$
J. Spectrophotometric determination of Mn in aqueous solution

METHODOLOGY

The following strategies from the active learning methodology are recommended:

- Simulations
- Written Reports
- Solving a problem posed
- Lectures
- Web-supported education
- Ethics across disciplines
- Laboratories
- Literature research
- Use of blogs
- Oral defense of proposal
- Execution rubrics in the laboratory and oral defense of the proposal

EVALUATION

Partial assignments	25%
Immersion experience	30%
Oral presentation	20%
Final project or exam	25%
Total	**100%**

LEARNING ASSESSMENT

The institutional assessment rubric is applied to the course's core activity.

BIBLIOGRAPHY

TEXTBOOK

Skoog, D. A., West, D. M., Holler, F. J., & Crouch, S. R. (2013). *Analytical chemistry: An introduction* (9th ed.). Cengage Learning.

REFERENCES

Andrade-Garda, J. M., Carlosena-Zubieta, A. (2017). *Problems of Instrumental Analytical Chemistry: A Hands-On Guide* (Essential Textbooks in Chemistry). (1st ed.). World Scientific Publishing Company.

Anjaneyulu, Y., Chandrasekhar, K. (2019). *A Textbook of Analytical Chemistry* (1st ed.). BSP BOOKS

Basha, M. (2019). *Analytical Techniques in Biochemistry* (Springer Protocols Handbooks). (1st ed.). Humana.

Carol, J. (2019). *Analytical Chemistry: Advanced Concepts and Applications* (1st ed.). Willford Press.

Farsalinos, K. E., Gillman, I. G., Hecht, S. S., Polosa, R., & Thornburg, J. (2016). *Analytical Assessment of e-Cigarettes: From Contents to Chemical and Particle Exposure Profiles* (Emerging Issues in Analytical Chemistry) (1st ed.). Elsevier.

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Harris, D. C. (2015). *Quantitative Chemical Analysis* (9th ed.). W. H. Freeman.

Ngambeki, W. (2019). *Introduction to Analytical Chemistry for University Students* (1st ed.). Tanzania Educational Publishers Ltd.

Pedersen-Bjergaard, S., Gammelgaard, B. & Halvorsen, T. G. (2019). *Introduction to Pharmaceutical Analytical Chemistry*. (2nd ed.). Wiley.

White, R. M., Moore, C. M. (2018). *Detection of Drugs and Their Metabolites in Oral Fluid* (Emerging Issues in Analytical Chemistry) (1st ed.). Elsevier.

For more information resources related to the course's topics, access the library's webpage http://biblioteca.sagrado.edu/

REASONABLE ACCOMMODATION

For detailed information on the process and required documentation you should visit the corresponding office. To ensure equal conditions, in compliance with the ADA Act (1990) and the Rehabilitation Act (1973), as amended, any student in need of reasonable accommodation or special assistance must complete the process established by the Vice Presidency for Academic Affairs.

ACADEMIC INTEGRITY

This policy applies to all students enrolled at Universidad del Sagrado Corazón to take courses with or without academic credit. A lack of academic integrity is any act or omission that does not demonstrate the honesty, transparency, and responsibility that should characterize all academic activity. Any student who fails to comply with the Honesty, Fraud, and Plagiarism Policy is exposed to the following sanctions: receive a grade of zero in the evaluation and / or repetition of the assignment in the seminar, a grade of F (*) in the seminar, suspension, or expulsion as established in the Academic Integrity Policy effective in November 2022.