Republic of the Philippines
OFFICE OF THE PRESIDENT
COMMISSION ON HIGHER EDUCATION

CHED MEMORANDUM ORDER (CMO)
No. 47
Series of 2017

SUBJECT: POLICIES, STANDARDS AND GUIDELINES FOR THE BACHELOR OF SCIENCE IN CHEMISTRY (BS CHEM) PROGRAM

In accordance with the pertinent provisions of Republic Act (RA) No. 7722, otherwise known as the "Higher Education Act of 1994," in pursuance of an outcomes-based quality assurance system as advocated under CMO No. 46, series of 2012, and for the purpose of rationalizing the chemistry education in the country with the end view of keeping apace with the demands of global competitiveness, by virtue of Commission en banc Resolution No. 231-2017 dated March 28, 2017, the following Policies and Standards are hereby adopted and promulgated by the Commission.

ARTICLE I
INTRODUCTION

Section 1. Rationale

This PSG updates the Policies and Standards for Bachelor of Science in Chemistry (BS Chem) presented in CMO No. 18, s. 2007.[1] It is aligned to the K-to-12 Basic Education Program and incorporates the New General Education Program prescribed by CMO No. 20, s. 2013. It also implements the outcomes-based education specified in CM0 No. 46, s. 2012.[2]

In order to ensure the employability of the graduates of the program, this PSG is harmonized with the Philippine Qualification Framework and the ASEAN Qualifications Reference Framework and other International Qualifications Framework. To guarantee quality consistent with global standards, it has been benchmarked with the American Chemical Society (ACS)-approved programs and the Chemistry Eurobachelor program.

This PSG also provides ample space for HEIs to innovate in the curriculum in line with the assessment of how best to achieve learning outcomes in their particular contexts and their respective missions.

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[1] The 2007 Polices, Standards and Guidelines for the Bachelor of Science in Chemistry program, per CHED Memorandum Order (CMO) No. 18, series of 2007, was preceded by a set of Policies and Standards for the Basic Sciences - B. S. Chemistry program per DECS Order No. 111, series of 1989, which was promulgated **in 1989** by the Bureau of Higher Education, BHE (the predecessor of the Commission on Higher Education, CHED). The **1989** BHE document underwent review and updating after the creation of CHED in 1994, and a proposed PSG was presented in a Public Hearing in 1999. Further revision was undertaken in the succeeding years, and the final version became the draft of the 2007 PSG.

[2] The curriculum described in the 2007 PSG was revised in 2014 to conform with the shift to learning competency-based standards / outcomes-based education specified in CMO 46 s. 2012.

ARTICLE II
AUTHORITY TO OPERATE

Section 2. Government Authority

All private higher education institutions (PHEIs) intending to offer Bachelor of Science in Chemistry (BS Chem) must first secure proper authority from the Commission in accordance with these PSGs. All PHEIs with existing BSChemistry program are required to shift to an outcomes-based approach based on this PSG. State universities and colleges (SUCs), and local colleges and universities (LUCs) should likewise strictly adhere to the provisions in these policies and standards.

ARTICLE III
GENERAL PROVISIONS

Per Section 13 of R.A. 7722, the higher education institution shall exercise academic freedom in its curricular offerings but must comply with the minimum requirements for specific programs, the general education distribution requirements and the specific professional courses.

Section 3. The Articles that follow give minimum standards and other requirements and prescriptions. The minimum standards are expressed as a minimum set of desired program outcomes which are given in Article IV, Section 6. The CHED designed a curriculum to attain such outcomes. This curriculum is shown in Article V, Section 9 as a sample curriculum. The number of units of this curriculum is herein prescribed as the minimum unit requirement under Section 13 of RA 7722. In designing the curriculum the CHED employed a curriculum map which is shown in Article V, Section 10 as a sample curriculum map.

Using an outcomes-based approach the CHED also determined appropriate curriculum delivery methods shown in Article V, Section 11. The sample course syllabi given in Article V, Section 13 show some of these methods.

Based on the curriculum and the means of its delivery, the CHED determined the physical resource requirements for the library, laboratories and other facilities and the human resource requirements in terms of administration and faculty as expressed in Article VI.

The objectives of the Policies and Standards are:

a. To set a minimum level of quality for the BS Chem program based on an outcomes-based approach within a life-long learning framework.

b. To enable institutions to produce chemists who can effectively participate as scientific professionals according to accepted global standards of the discipline.

Section 4. The HEIs are allowed to design curricula suited to their own contexts and missions provided that they can demonstrate that the same leads to the attainment of the required minimum set of outcomes, albeit by a different route. In the same vein, they have latitude in terms of curriculum delivery and in terms of specification and deployment of human and physical resources as long as they can show that the attainment of the program outcomes and satisfaction of program educational objectives can be assured by the alternative means they propose.

The HEIs can use the CHED Implementation Handbook for Outcomes-Based Education (OBE) and the Institutional Sustainability Assessment (ISA) as a guide in making their submissions from sections in Article VII, Section 21.

ARTICLE IV
PROGRAM SPECIFICATIONS

Section 5. Program Description

5.1 Degree Name

The degree program described herein shall be called Bachelor of Science in Chemistry (BSChem).

5.2 Nature of the Field of Study

Chemistry is the branch of the natural sciences that studies matter, its composition, properties and reactions. It includes the "study, analysis, modification and calculations of physic-chemical or biochemical properties of matter. Chemistry includes the atomic, molecular, surface and supramolecular composition and structure of matter, properties and reactions, the changes which matter undergoes, the energy involved, and the conditions under which such changes occur" (R.A. 10657 Chemistry Profession Act of 2015). It is a broad field, which overlaps with other fields particularly biology, physics and geology. Chemistry also has a role of interconnecting other fields and has thus been described as the Central Science.

The core disciplines of chemistry are inorganic, organic, analytical, physical chemistry and biochemistry.

Chemistry is beneficial to society. It is the foundation science for many industrial and agricultural processes that produce useful products that contribute to the improvement of the quality of life. It impacts on human health - producing materials, developing methods and advancing knowledge towards improved health care, enhanced public health and safety, safe and affordable food supply, and a sustained wholesome environment. It plays a key role in the development of materials and processes for the production of sustainable renewable energy. It is indeed a science of numerous opportunities.

Chemistry engages international concern and action. It espouses collaborative efforts that span borders and cultures towards the

enhancement of chemical knowledge and processes for the benefit of society and the environment. It promotes a common global standard of excellence and relevance in scientific endeavors and output.

Chemistry is essential for the continued development of the Philippines. Therefore, any policy designed to upgrade chemistry education at the college level should take into account the diversity of chemistry, the need for trained personnel and the significant investment needed to sustain an acceptable standard of chemistry education.

5.3 Program Goals

The program aims to:

i. Produce graduates who comply with the current qualification requirements of professional chemists for local and overseas employment and entrepreneurship.

ii. Prepare students for higher studies in chemistry and in other fields.

5.4 Specific Professions/careers/occupations or trades that BS Chem graduates may go into.

With a BS Chem degree and professional license, a graduate can be employed as laboratory chemist in industries and companies that deal with chemicals, food and beverage, cosmetics, pharmaceuticals, oil and petroleum, mineral and metals, textile, agricultural products, pulp and paper, analytical chemistry services, quality control, research among others. Graduates can also be employed in government agencies with similar lines of concern and in crime laboratories for forensic analysis.

The BS Chem degree holder can also secure non-laboratory work such as science communication, technical writing, entrepreneurship, marketing and management, product sales, chemical information services, health and safety, intellectual property, project management, etc.

A graduate of Chemistry program can be employed in colleges and universities. Further training (MS and PhD) would qualify graduates for tenured positions in the academe.

5.5 Allied Fields

The following fields such as: marine science, geological sciences, physics, molecular biology and biotechnology, materials science, pharmaceutical science, food science, agricultural sciences, chemical engineering, forensic sciences and environmental science, are recognized as specializations allied to chemistry. Graduates of these fields may be considered to teach non-professional or elective courses in the BS Chem program.

Section 6. Program Outcomes

The minimum standards for the BS Chem program are expressed in the following minimum set of program outcomes:

6.3 Specific to BS Chem

A graduate of the program should be able to:

A. Demonstrate a broad and coherent knowledge and understanding in the core areas of chemistry: inorganic, organic, physical, biological and analytical chemistry; and in addition the necessary background in mathematics and physics
B. Gather data using standard laboratory equipment, modern instrumentation and classical techniques
C. Identify and solve problems involving chemistry, using current disciplinary and interdisciplinary principles
D. Qualify for further study and/or for entry-level professional employment in the general workplace
E. Work effectively and independently in multi-disciplinary and multi-cultural teams
F. Act in recognition of professional, social, and ethical responsibility
G. Effectively communicate orally and in writing using both English and Filipino
H. Articulate and discuss the latest developments in the specific field of practice (PQF level 6 descriptor)interpret relevant scientific data and make judgments that include reflection on relevant scientific and ethical issues
I. Preserve and promote "*Filipino historical and cultural heritage*"

6.2 Common to a horizontal typology type as defined in CMO No. 46, s. 2012

In line with the policies defined in CMO No. 46, s 2012, graduates should be able to:

A. Promote service in one's profession
B. Participate in various types of employment, development activities, and public discourses particularly in response to the needs of the community one serves
C. Participate in the generation of new knowledge or in research and development projects
D. Support "national, regional and local development plans"

A HEI, as an option, may adopt mission-related program outcomes that are not included in the minimum set.

Section 7. Sample Performance Indicators

Performance indicators assist in the evaluation of student learning or the achievement of the program outcomes. These are demonstrable traits

The graduate of the BS Chem program is expected to possess a wide range of abilities and skills.[3] These are divided into three broad categories:

a. Chemistry-related cognitive abilities and skills, i.e. abilities and skills relating to intellectual tasks, including analysis of problems and systematic problem-solving;

b. Chemistry-related practical skills, e.g. skills relating to the conduct of laboratory work, proper use of sophisticated instrumentation, safe handling of chemicals and waste minimization; and

c. Generic skills that may be develop during the course and are applicable in many other contexts.

These competencies may be reviewed and include in the performance indicators.

Chemistry-related cognitive abilities and skills

a. Conceptual understanding and problem solving skills in the fundamental chemical sub-fields of analytical, organic, inorganic, biochemistry and physical chemistry.
b. A foundation of physics and mathematics and ability to apply them to chemical problems.
c. Skills in the evaluation, interpretation and synthesis of chemical information and data, and to draw conclusions from them; ability to assess primary papers critically
d. Ability to recognize and implement accurate and precise scientific measurements
e. Computational and data processing skills, relating to chemical information and data.

Chemistry-related practical skills

f. Skills required in good laboratory practices including safety, waste management and record keeping.
g. Proper use of modern chemical instrumentation
h. Skills required for the conduct of standard laboratory procedures involved and use of instrumentation in analytical and synthetic work, in relation to both organic and inorganic systems
i. Ability to use the scientific literature effectively and evaluate technical articles critically
j. Skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof
k. Ability to evaluate and interpret data derived from laboratory observations and measurements in terms of their significance, and to relate them to appropriate theories

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[3]*Adapted from the Chemistry Eurobachelor program, a framework developed by European Chemistry Thematic Network. (www.cpefr.fr/ectn/tuning%20eurobachelor.htm).*

l. Ability to design experiments and understand the limitations of the experimental approach; ability to design suitable alternative procedures and methods

Generic skills

m. Communication skills, covering both written and oral communication. This includes the ability to present scientific information in a clear and concise manner and to discuss them intelligently, both in writing and orally.
n. Ability to dissect a problem into its key features; Problem-solving skills, relating to qualitative and quantitative information
o. Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units
p. Ability to use information technology in information-retrieval, evaluation, and dissemination
q. Interpersonal skills relating to the ability to interact with other people and to work in a team; ability to collaborate with other researchers
r. Study and self-development skills needed for continuing professional development and life-long learning.
s. Ability to exercise ethical principles and social responsibility in their professional and personal endeavors.

A sample map can be found in **Annex A1.**

ARTICLE V
CURRICULUM

Section 8. Curriculum Description

Chemistry is a central and essential science and is a fundamental part of many other disciplines. Therefore, the curriculum for BS Chem should be built around a well-defined core of subjects that covers the fundamental aspects in sufficient depth and at the same time allow for flexibility to cover areas and applications in the allied disciplines. The curriculum should also provide the necessary background in mathematics, physics, biology, information and computational sciences to prepare Chemistry graduates for higher levels of technical expertise.

The purpose of this is to ensure a common minimum standard for the BS Chem degree. However, the individual Chemistry institutions are given the flexibility to offer courses and topics of their preference beyond the minimum standards. It should be also emphasized that flexibility is allowed as long as the basic topics are covered.

The curriculum should cover the following main aspects of chemistry in order to significantly achieve the program outcomes[4].

a. Major aspects of chemical terminology, nomenclature, conventions and units

[4] Adapted from the Chemistry Eurobachelor program, a framework developed by European Chemistry Thematic Network. (www.cpefr.fr/ectn/tuning%20eurobachelor.htm).

b. The structure and reactivity of the major classes of organic and inorganic compounds
c. The major types of chemical reactions and the main characteristics associated with them
d. The principles and procedures used in basic types of classical and instrumental chemical analysis
e. Proper handling of numerical data, error, precision, estimation of error; principles of sampling
f. The principal techniques of structural determination by spectroscopic techniques
g. The characteristics of the different states of matter and the theories used to describe them
h. The principles of quantum mechanics and their application to the description of the structure and properties of atoms and molecules
i. The principles of thermodynamics and their applications to chemistry
j. The kinetics of chemical change, including catalysis; the mechanistic interpretation of chemical reactions
k. The characteristic properties of elements and their compounds, including group relationships and trends within the Periodic Table
l. The structural features of chemical elements and their compounds, including stereochemistry
m. The properties and chemical reactivity of organic functional groups
n. Basic synthetic strategies in organic chemistry, including catalysis
o. The relation between bulk properties and the properties of individual atoms and molecules, including macromolecules (both natural and synthetic), polymers and other related materials
p. Molecular basis of physical and biological phenomena
q. Challenges and ethical issues in science, in general, and Chemistry, in particular
r. Chemical safety and waste management
s. New developments in chemistry and chemical techniques

Section 9. Sample Curriculum

9.1 Curriculum Components

The components of the BS Chem curriculum are listed in Table 1 together with the minimum number of units in each component.

Table 1. Components of the BS Chemistry curriculum and their corresponding units

COMPONENTS	UNITS
a. General Education Curriculum	*36*
b. Core Courses	
Ancillary Courses	*14*
Chemistry[*]	*54*
c. Electives[*]	*6*
d. Thesis and Professional Engagement[*]	*6*
e. Physical Education (PE)	*8*
f. National Service Training Program (NSTP)	*6*
Total	***130***

[*] *Counted towards the 60-unit course requirement of the R.A. 10657, Chemistry Profession Act of 2015*

General Education Courses (36 units)

The general education and legislated courses will follow the CHED Memorandum No. 20 series of 2013 (36 units). The list of GE courses is in Table 2.

Table 2. GE courses and corresponding units

Core courses (24 units)	
1. Understanding the Self (Nature of identity)	3 units
2. Readings in Philippine History	3 units
3. Mathematics in the Modern World (Application of Mathematics in daily life)	3 units
4. Purposive Communication (Writing, Speaking and presenting to different audiences)	3 units
5. Art Appreciation	3 units
6. Science, Technology and Society	
7. Ethics	3 units
8. The Contemporary World (Globalization and its impact on individuals, communities and nations)	3 units 3 units
Elective courses (9 units)	
9. Mathematics, Science and Technology (e.g. Environmental Science)	3 units
10. Arts and Humanities (e.g. Great Books)	3 units
11. Social Sciences and Philosophy (e.g. Entrepreneurship)	3 units
Rizal course (3 units)	

Core Courses (68 units)

Ancillary courses (14 Units)

The BS Chem program requires 14 units of ancillary courses. Table 3 lists the ancillary courses that should be taken by students in the program. The minimum number of required units per area is also given in the table below.

Table 3. List of ancillary courses and corresponding units

Non-chemistry core courses (14 units)	
1. Math Analysis 1	3 units
2. Math Analysis 2	3 units
3. Physics 1	4 units
4. Physics 2	4 units

Core Chemistry Courses (54 Units)

The core chemistry courses are listed in Table 4 and their corresponding minimum number of units. An equivalent combination of lecture and laboratory courses may be offered provided the basic topics and skills in each core area are covered.

Table 4. List of Chemistry core courses

Level 1 chemistry core courses (22 units)	
1. Principles of Chemistry	5 units
2. Inorganic Chemistry 1	3 units
3. Organic Chemistry 1	5 units
4. Physical Chemistry 1	4 units
5. Analytical Chemistry 1	5 units
Level 2 courses (22 units)	
1. Inorganic Chemistry 2	3 units
2. Organic Chemistry 2	5 units
3. Physical Chemistry 2	4 units
4. Biochemistry 1	5 units
5. Analytical Chemistry 2	5 units
Level 3 courses (10 units)	
1. Analytical Chemistry 3	4 units
2. Physical Chemistry 3	3 units
3. Biochemistry 2	3 units

Electives (6 units)

The BS Chem curriculum includes electives. The Chemistry department may wish to emphasize special areas of Chemistry through the electives. A list of suggested electives is shown in Table 5

Table 5. List of suggested electives

Elective courses (6 units)	
1. Advanced Organic Chemistry	3 units
2. Materials Chemistry	3 units
3. Environmental Chemistry	3 units
4. General Industrial Chemistry	3 units
5. Food Chemistry	3 units
6. Molecular Spectroscopy	3 units
7. Biotechnology / Microbiology	3 units
8. Nanotechnology	3 units
9. Biomolecules	3 units
10. Entrepreneurship	3 units
11. Special Topics in Chemistry	1-3 units

Thesis or Research and Professional Engagement (6 units)

Students should work on a thesis and undertake professional engagement in various settings such as laboratories, research institutions, scientific organizations, and policy making bodies in government, industry and academe. HEIs shall have the prerogative to choose a mode of implementing this requirement based on the available resources within the institution and opportunities for collaboration with suitable outside organizations.

Professional engagement should be in accordance with CMO Nos. 23 and 24 series of 2009.

Table 6. *Thesis and Professional Engagement Courses**

1. Thesis	3-6 units
2. Professional Engagement	0-3 units

**should have a combined total of 6 units*

9.2 Program of Study

A sample program of study and the recommended sequence of courses is given in Table 7 below. Institutions may modify the curriculum to suit their particular requirements and thrusts. Institutions may choose to offer certain courses during the summer.

Table 7. Sample program of study and recommended sequence of courses

SEMESTER 1		**SEMESTER 2**	
Gen. Ed. 1	3 units	Gen. Ed. 3	3 units
Gen. Ed. 2	3 units	Gen. Ed. 4	3 units
Math Analysis 1	3 units	Physics 1	4 units
Principles of Chemistry	5 units	Math Analysis 2	3 units
PE	2 units	Inorganic Chemistry 1	3 units
NSTP	3 units	PE	2 units
		NSTP	3 units
TOTAL	**19 units**	**TOTAL**	**21 units**

SEMESTER 3		**SEMESTER 4**	
Gen. Ed. 5	3 units	Gen. Ed. 9	3 units
Gen. Ed. 6	3units	Gen. Ed. 10	3 units
Physics 2	4 units	Organic Chemistry 2	5 units
Analytical Chemistry 1	5 units	Physical Chemistry 1	4 units
Organic Chemistry 1	5 units	Analytical Chemistry 2	5 units
PE	2 units	PE	2 units
TOTAL	**22 units**	**TOTAL**	**22 units**

SEMESTER 5		**SEMESTER 6**	
Gen. Ed. 7	3 units	Physical Chemistry 3	3 units
Biochemistry 1	5 units	Elective 1	3 units
Physical Chemistry 2	4 units	Rizal	3 units
Analytical Chemistry 3	4 units	Biochemistry 2	3 units
		Thesis 1	1 unit
TOTAL	**16 units**	**TOTAL**	**13 units**

SEMESTER 7		**SEMESTER 8**	
Gen. Ed. 8	3 units	Thesis 3	1 unit
Gen. Ed. 11	3 units	Professional Engagement	3 units
Elective 2	3 units		
Inorganic Chemistry 2	3 units		
Thesis 2	1 unit		
TOTAL	**13 units**	**TOTAL**	**4 units**
		TOTAL NUMBER OF UNITS	**130**

Section 10. Sample Curriculum Map

The Curriculum map presents where the learning outcomes are addressed and it provides a means to determine the achievement of the program outcomes.

Based on the required minimum set of program outcomes, the Commission has determined a program of study that leads to the attainment of the outcomes. This program of study specifies a set of courses sequenced based on flow of content, with each course having a specified title, description, course outcome and credit unit. For this purpose, a sample curriculum map is shown in **Annex A**. It is a matrix of all courses and the minimum set of program outcomes showing which outcome each course addresses. The map also determines whether the outcomes are aligned with the curriculum.

Higher education institutions shall formulate its curriculum map based on its own set of program outcomes and courses.

Section 11. Curriculum Delivery

The mode of delivery of each course is indicated in the course syllabi discussed above. A variety of instruction methods can be employed by the teachers and include innovations in the strategies.

Some sample delivery/ methods/ activities include:

- Lectures
- Laboratory experiments
- Demonstration
- Visualization exercise
- Concept maps
- Film showing
- Class and group discussions
- Problem solving exercises
- Computer modeling
- Field trip
- Tutorials

Section 12. Assessment

The assessment of the achievement of the students should reflect the objectives, knowledge, skills and abilities identified in the program outcome.

Some means of assessment include:

- formal examinations
- laboratory reports and skills
- problem-solving exercises
- oral presentations/recitation
- planning, conduct and reporting of project work

Some additional means of assessment include:

- Essay assignments
- Portfolio on chemical activities undertaken
- Literature surveys and evaluations
- Collaborative project work
- Preparation and displays of 'posters' reporting project work
- Reports on external placements (where appropriate)

Section 13. Sample Syllabi for Core Chemistry Courses

The course specifications provided in this CMO in **Annex B** apply only to the core courses and indicate the minimum course outcomes to be achieved by the students at the end of each course.

There are five (5) core courses for the BS Chem program with varying designated number of units: Inorganic Chemistry, Analytical Chemistry, Organic Chemistry, Biochemistry and Physical Chemistry. In addition, the program requires a minimum total of six (6) units of undergraduate thesis and professional engagement. There are six (6) units of elective courses.

It is suggested that the introductory and/or concluding part of each Chemistry course present an informative survey of advances and prospects in this area in order to elicit more interest from the student. While the course must continue to impart skills to the student, it should also try to sustain or increase the interest of the student in Chemistry.

The HEIs shall formulate the syllabus for all the courses in their respective programs.

ARTICLE VI
REQUIRED RESOURCES

Section 14. Instructional Standards

HEIs shall at all times maintain a high standard of instruction through:

a. Periodic evaluation (including teaching competence, research capabilities, scholarly outputs, dedication to work and integrity, community engagement) of the teachers by students, peers and the chairman of the department;
b. Provision and maintenance of adequate laboratory facilities;
c. Provision of at least one laboratory instructor for every 25 students;
d. Keeping the number of students in a regular lecture class to not more than forty (40) except when provisions are made for a larger class;
e. Adoption of textbooks and other instructional materials that are up to date (ideally not older than 5 years) in content and not in violation of any Philippine laws;

f. Use of modern techniques and technology for improving teaching and learning quality;
g. Periodic evaluation of the chemistry curriculum at least every 5 years;
h. Definite and valid system of evaluating student class performance; and
i. System of awards and recognition for outstanding faculty and student performance.

Section 15. Administration

The BS Chem Program shall be administered by a Chemistry department or institute headed by its own chair or director and having its own set of full-time faculty.

A higher education institution offering a science program shall have a full-time Dean or Department Chair.

15.1 Dean of the unit/college

The dean of the college administering the BS Chem program must possess a master's degree in a discipline offered within the college.

15.2 Head of the chemistry unit/department

The head of the Chemistry department or institute offering a BS Chem program must at least be a MS Chemistry degree (with thesis) holder or allied fields (with thesis) and a registered chemist.

Section 16 Faculty

16.1 Qualification of faculty

a. All faculty teaching in the BS Chem program must have the minimum of a Master's degree in chemistry or any allied field cited in Section 5.5.
b. All faculty members handling professional chemistry courses must be registered chemists.
c. The expertise of the faculty members must represent the major fields of chemistry.

16.2 Full time faculty members

a. At least 50% of the teaching staff in the BS Chem program must be full-time faculty members.
b. At least one of the full-time faculty must have an earned doctorate in chemistry.

16.3 Teaching Load

Teaching load requirements for faculty members teaching in the BS Chem program shall be as follows:

a. Full time faculty members should not be assigned more than four (4) different courses within a semester.
b. In no instance should the aggregate teaching load of a faculty

member exceed 30 units per semester (inclusive of overload and teaching loads in other schools).

c. Teaching hours per day should not exceed the equivalent of 6 lecture hours.

16.4 Faculty academic load

The regular fulltime load of a chemistry faculty member shall be defined as the total academic load, which is an aggregation or combination of teaching, research and administration

The regular academic load of PhD/MS Faculty should include research and/or development projects and community engagement.

The allotment of a research load to the faculty with corresponding compensation is highly encouraged.

Only faculty members with graduate degrees by research should be assigned as thesis advisers.

16.5 Faculty Development

The institution must have a system of staff development. It should encourage the faculty to:

a. pursue further studies or post-graduate training;
b. undertake research activities and publish their research output;
c. give lectures and present papers in national/international conferences, symposia and seminars;
d. attend seminars, symposia and conferences for continuing education; and
e. be active members of professional organizations.

The institution must provide opportunities and incentives such as:

a. financial support for advanced studies;
b. study leave with pay;
c. reduced teaching load to complete a thesis or to carry out research activities;
d. travel grants which could include conference registration, accommodation and transportation for academic development activities such as special skills training and attendance in national/ international conferences, symposia and seminars; and
e. awards & recognition.

Section 17. Library

Library personnel, facilities and holdings should conform to existing CHED requirements for libraries which are embodied in a separate CHED issuance. The library must maintain a collection of updated and appropriate/suitable textbooks and references used for the core courses in the curriculum. Library resources should complement curriculum delivery to optimize the achievement of the program outcomes for the BS Chem program.

The HEI is likewise encouraged to maintain journals and other non-print materials relevant to chemistry education to aid the faculty and students in their academic work. Electronic resources could complement a library's book collection but should not be considered as a replacement for the same.

Internet access is encouraged but should not be made a substitute for book holdings and/or on-line subscription to books and journals.

Libraries shall participate in inter-institutional activities and cooperative programs whereby resource sharing is encouraged.

Section 18. Laboratory and Facilities

HEIs should provide the appropriate facilities and equipment to ensure the effective delivery of the courses and achievement of program outcomes. There should be a system of updating and enhancing the needed facilities, computing software and equipment to be provided to the students.

18.1 Laboratory Requirements

Laboratories should conform to existing requirements as specified by law (RA 6541, "The National Building Code of the Philippines", RA 10657, "Chemistry Profession Act" and Presidential Decree 856, "Code of Sanitation of the Philippines").

Table 8. List of Required and Recommended Equipment for the Laboratory Courses

Instrument	
Analyzer, Voltammetric	Pipettors
Autoclave	Polarimeter
Balance, analytical/electronic	Polymerase Chain Reaction apparatus
Balance, top loading/electronic	Pump, vacuum
Barometer	Refractometer
Constant volume calorimeter	Rotary evaporator
Centrifuge	Shaker, temperature-controlled water bath
Chromatograph, GC/LC	Soxhlet Extractor
Electrophoresis apparatus	Spectrometer, Atomic Absorption
Fume hood	Spectrometer, Fourier Transform Infrared
Furnace	Spectrometer, Ultraviolet Visible
Hot plate	Tensiometer
Melting point apparatus	Ultraviolet lamp
Meter, conductivity	Viscometer
Meter, multi	
Microscope	
Mixer, vortex	
Oven, laboratory	
Ph meter, bench top	

Adequate instrumentation and support facilities are crucial to the quality of the BS Chem program. The proper training of the Chemistry student requires that the essential equipment is available in the laboratory.

Table 9. Lists of support facilities required for the laboratory courses.

Support facility
Fume hood / Cupboard
Safety shower
Eyewash
First-aid cabinet and medicines
Fire Extinguisher

The following points should be emphasized:

- The Chemistry department must see to it that the condition in the laboratory considers human safety such as proper ventilation, access to emergency and first aid equipment, among others.
- The list of instruments is intended for undergraduate BS Chem laboratory courses. As such, the purpose of the instruments is mainly instructional. In general, the simpler, more robust models are preferred.
- The Chemistry department must see to it that the conditions for proper operation and maintenance of the instrument are adequate, in particular: stability of electricity, protection from dust, heat and other inappropriate conditions.
- There should be faculty and/or staff who are adequately trained and knowledgeable in the principles, operation and maintenance of the equipment.
- The students should be properly trained in the principles and operation of various equipments. Students should have reasonable access to the instruments.
- Students should be properly trained / informed about proper disposal of chemical waste.

18.2 Laboratory Staff

a. Each department shall have a full-time registered chemist to supervise laboratory operations.
b. Each department shall have a full-time registered chemical technician to maintain laboratory facilities. The chemical technician must be supervised by a registered chemist.
c. Each department with laboratory/ies shall assign at least one personnel as the laboratory safety officer /chemical waste manager available at all times to respond to emergencies such as fire, chemical accidents, first aid needs, earthquakes, and other exigencies.

18.3 Safety

18.3.1 Staff

The HEI should appoint safety officer/s to take charge of the following:

a. Chemical safety
b. Maintenance of equipment and other chemistry facilities
c. Chemical inventory
d. First aid

e. Emergency measures, including fire, earthquake, and others
f. Security
g. Chemical waste disposal

The safety officer shall be properly trained, instructed and equipped to oversee the various safety measures including waste disposal system. Schools shall ensure that safety officers undergo regular retraining and upgrading.

Laboratory safety officers shall be familiar with the emergency features of the laboratory and shall know the emergency procedures in cases of fires, accidents, earthquakes, and chemical spills. They shall be familiar with basic first aid procedures.

18.3.2 Safety and emergency fixtures and equipment

The Chemistry department must see to it that appropriate safety and emergency fixtures and equipment are available, easily accessed when needed and maintained regularly.

18.3.3 Staff training

The Chemistry department should hold special training and instruction for the staff and students and periodically hold drills involving staff and students.

18.3.4 Safety practices and measures

The Chemistry Department must implement at all times safety practices and measures in the laboratory. The department must document safety policies and procedures in a Safety Manual.

Chemical should be stored appropriately and in accordance with local environmental laws and regulations.

Chemical waste must be disposed properly and in accordance with local and/or Department of Environmental and Natural Resources (DENR) environmental laws and regulations.

ARTICLE VII
QUALITY ASSURANCE

Section 19. Assessment and Evaluation

The institution/department shall have in place a program assessment and evaluation system. The HEI must show this in their syllabi and catalogue. Institutions may refer to the **CHED Implementation Handbook for Outcome-Based Education (OBE) and the Institutional Sustainability Assessment (ISA)** for guidance.

Section 20. Continuous Quality Improvement (CQI) Systems

The HEI shall maintain at all times a high standard of instruction and delivery through the establishment of a program level Continuous Quality Improvement system. Institution/department must show organizational and process plans, and implementation strategies. Institutions may refer to the **CHED Implementation Handbook for Outcome-Based Education (OBE) and the Institutional Sustainability Assessment (ISA)** for guidance.

Section 21. CHED Monitoring and Evaluation

The CHED, in harmony with existing guidelines on monitoring and evaluation shall conduct regular monitoring on the compliance of respective HEIs to these policies and standards. An outcomes-based assessment instrument shall be used during the conduct of monitoring and evaluation.

Using the CHED Implementation Handbook for OBE and ISA as references, the HEIs shall develop the following items which will be submitted to CHED when they apply for a permit for a new program:

1. The complete set of program outcomes, including its proposed additional program outcomes.
2. Its proposed curriculum and its justification including a curriculum map.
3. Proposed performance indicators for each outcome. Proposed measurement system for the level of attainment of each indicator.
4. Proposed outcomes-based syllabus for each course.
5. Proposed system of program assessment and evaluation
6. Proposed system of program Continuous Quality Improvement (CQI).

ARTICLE VIII
TRANSITORY, REPEALING AND EFFECTIVITY PROVISIONS

Section 22. Transitory Provision

All private HEIs, state universities and colleges (SUCs) and local universities and colleges (LUCs) with existing authorization to operate the Bachelor of Science in Chemistry program are hereby given a period of three (3) years from the effectivity thereof to fully comply with the requirements in this CMO. However, the prescribed minimum curricular requirements in this CMO shall be implemented starting Academic Year 2018-2019.

Section 23. Repealing Clause

All CHED issuances, rules and regulations or parts thereof, which are inconsistent with the provisions of this CMO, are hereby repealed.

Section 24. Effectivity Clause

This CMO shall take effect fifteen (15) days after its publication in the Official Gazette or in a newspaper of general circulation. This CMO shall be implemented beginning Academic Year 2018-2019.

Quezon City, Philippines, May 17 2017.

For the Commission:

PATRICIA B. LICUANAN, Ph.D.
Chairperson

Attachments:

ANNEX A – Curriculum Mapping
ANNEX A1 – BS Chemistry Program Outcomes & Performance Indicators Map
ANNEX B – Course Specifications
ANNEX C – Safety Measures

ANNEX A
CURRICULUM MAPPING
BS CHEMISTRY

I. Program Outcomes

At the end of this program, the students are expected to be able to:

A. demonstrate a broad and coherent knowledge and understanding in the core areas of chemistry: inorganic, organic, physical, biological and analytical chemistry; and in addition the necessary background in mathematics and physics
B. gather data using standard laboratory equipment, modern instrumentation and classical techniques
C. identify and solve problems involving chemistry, using current disciplin9ary and interdisciplinary principles
D. qualify for further study and/or for entry-level professional employment in the general workplace (To vary for university, colleges and professional schools)
E. work effectively and independently in multi-disciplinary and multi-cultural teams (PQF level 6 descriptor)
F. act in recognition of professional, social, and ethical responsibility
G. effectively communicate orally and in writing using both English and Filipino
H. articulate and discuss the latest developments in the specific field of practice (PQF level 6 descriptor)
I. interpret relevant scientific data and make judgments that include reflection on relevant scientific and ethical issues
J. preserve and promote "*Filipino historical and cultural heritage*" (based on RA 7722)

COURSE	RELATIONSHIP OF COURSES TO PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
A. General Education Core Courses										
Understanding the Self (Nature of identity)					✓	✓	✓			✓
Readings in Philippine History					✓	✓	✓			✓
Mathematics in the Modern World (application of mathematics in daily life)					✓	✓	✓			✓
Purposive Communication (Writing, speaking and presenting to different audiences)					✓	✓	✓			✓
Art Appreciation					✓	✓	✓			✓
Science, Technology and Society					✓	✓	✓	✓	✓	✓
Ethics					✓	✓	✓		✓	✓
The Contemporary World (Globalization and its impact on individuals, communities and nations)					✓	✓	✓	✓		✓

COURSE	RELATIONSHIP OF COURSES TO PROGRAM OUTCOME									
B. General Education Elective Courses	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Mathematics, Science and Technology (e.g. Environmental Science)					✓	✓	✓			✓
Arts and Humanities (e.g. Great Books)					✓	✓	✓			✓
Social Sciences and Philosophy (e.g. Entrepreneurship)					✓	✓	✓			✓
C. General Education Mandated Course										
Life and Works of Rizal - 3 Units					✓		✓			✓
E. Ancillary Core Courses										
Math Analysis 1	✓				✓	✓			✓	
Math Analysis 2	✓				✓	✓			✓	
Physics 1	✓	✓				✓	✓		✓	
Physics 2	✓	✓				✓	✓		✓	
F. Chemistry Core Courses										
Principles of Chemistry (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Inorganic Chemistry 1 (lec or lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Organic Chemistry 1 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Analytical Chemistry 1 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Physical Chemistry 1 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Inorganic Chemistry 2 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Organic Chemistry 2 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Physical Chemistry 2 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Biochemistry 1 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Analytical Chemistry 2 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Biochemistry (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Analytical Chemistry 3 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Physical Chemistry 3 (lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Biochemistry 2 (lec or lec/lab)	✓	✓	✓	✓	✓	✓	✓	✓	✓	

G. Chemistry Electives										
Advanced Organic Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Materials Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Environmental Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Natural Products Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Food Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
General Industrial Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Biotechnology / Microbiology	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nanotechnology	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Molecular Spectroscopy	✓	✓	✓	✓	✓	✓	✓	✓	✓	
H. Research / Professional Engagement courses										
Thesis	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Professional Engagement	✓	✓	✓	✓	✓	✓	✓	✓	✓	

ANNEX A1
BS Chemistry Program Outcomes and Performance Indicators Map

PROGRAM OUTCOMES	PERFORMANCE INDICATORS																	
	Cognitive Abilities and Skills					Practical Skills						Generic Skills						
At the end of this program, the students are expected to be able to:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
A. demonstrate a broad and coherent knowledge and understanding in the core areas of chemistry: inorganic, organic, physical, biological and analytical chemistry; and in addition the necessary background in mathematics and physics	✓	✓	✓		✓					✓	✓	✓	✓	✓				
B. gather data using standard laboratory equipment, modern instrumentation and classical techniques			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			
C. identify and solve problems involving chemistry, using current disciplinary and interdisciplinary principles;	✓	✓	✓	✓	✓					✓			✓	✓				✓
D. work effectively and independently in multi-												✓				✓	✓	✓

disciplinary and multi-cultural teams																		
PROGRAM OUTCOMES	**PERFORMANCE INDICATORS**																	
	Cognitive Abilities and Skills					**Practical Skills**						**Generic Skills**						
At the end of this program, the students are expected to be able to:	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**
E. act in recognition of professional, social, and ethical responsibility						✓						✓			✓	✓	✓	✓
F. effectively communicate orally and in writing using both English and Filipino												✓			✓			✓
G. articulate and discuss the latest developments in the specific field of practice	✓											✓			✓		✓	
H. interpret relevant scientific data and make judgments that include reflection on relevant scientific and ethical issues	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
I. preserve and promote "*Filipino historical and cultural heritage*"												✓	✓	✓	✓	✓	✓	✓

ANNEX B. COURSE SPECIFICATIONS

BS Chemistry

PRINCIPLES OF CHEMISTRY

A. Course Details

COURSE NAME	**Principles of Chemistry**
COURSE DESCRIPTION	The course entitled "Principles of Chemistry" emphasizes fundamental chemical concepts and inorganic structures. Topics to be discussed include: atomic and molecular structure; the periodic table and periodicity; chemical bonding; thermochemistry; kinetics and reaction rates, chemical equilibrium, acid-base and solubility equilibria; and basic thermodynamics. Electrochemistry, nuclear chemistry and the descriptive chemistry of the representative elements may be introduced as optional enrichment topics to advanced students Laboratory experiments are designed to complement the lectures.
NUMBER OF UNITS	3 units lec/2 units lab
Pre-Requisite	One year of high school chemistry
Co-Requisites	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Describe the basic concepts of quantum theory; provide a basic quantum mechanical description of the hydrogen atom; determine the electron configurations of atoms; and use periodic trends to make predictions about atomic and chemical properties.	✓		✓	✓			✓	✓		
Describe ionic and covalent bond formation; compare properties of ionic and covalent compounds; write	✓		✓	✓			✓			

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
Lewis structures of molecules to predict the geometry and polarity of molecules										
Describe the valence bond and molecular orbital theories of bonding; explain the concept of hybridization of atomic orbitals	✓		✓	✓			✓			
Identify and describe the intermolecular attractive forces and how they affect the properties of the states of matter and phase behavior; interpret a phase diagram	✓		✓	✓			✓			
Classify solids by type and crystalline structure	✓		✓	✓			✓			
Describe various types of solutions; calculate the concentrations of solutions using various concentration units; explain the factors affecting solubility; define the colligative properties and perform calculations involving the colligative properties of nonelectrolyte and electrolyte solutions	✓		✓	✓			✓			
Write and interpret a rate law; calculate reactant concentration as a function of time using a given rate law; state and explain factors that affect reaction rates; derive simple reaction mechanisms based on a given set of elementary reactions	✓		✓	✓			✓			
Describe dynamic chemical equilibrium and factors affecting it; write equilibrium constant expressions and calculate their values; use Le Chatelier's Principle to determine shifts in equilibrium	✓		✓	✓			✓			
Differentiate the theories of acids and bases; describe the behavior of strong and weak acids and bases in aqueous solutions; calculate for pH of solutions.	✓		✓	✓			✓			
Apply chemical equilibrium concepts to acids and bases and insoluble salts	✓		✓	✓			✓			
Describe the thermodynamic changes of enthalpy, entropy, and Gibbs free energy that accompany a chemical reaction and use standard	✓		✓	✓			✓			

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
tables to calculate their values for a given chemical reaction.										
Use the laws of thermodynamics to predict the spontaneity of chemical processes including electrochemical processes.	✓		✓	✓			✓			
Evaluate the relationship between chemistry and other disciplines, between chemistry and society			✓		✓	✓	✓	✓	✓	✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment*
	Atoms and the Periodic Table • Subatomic particles and atomic structure • Atomic number, mass number, and isotopes • Nuclear stability • Average atomic mass • The periodic table • The mole and molar mass	EXAMPLE:	EXAMPLE: formal examinations, short quizzes, laboratory reports
	Quantum Theory and the Electronic Structure of Atoms • Energy and energy changes • The nature of light • Bohr's theory of the hydrogen atoms • Wave properties of mater • Quantum mechanics • Quantum numbers • Atomic orbitals • Electron configurations • Electron configurations and the periodic table		

	Periodic Trends of the Elements • The modern periodic table • Effective nuclear charge and periodic trends in the properties of elements • Electron configuration of ions • Ionic radius		
	Ionic and Covalent Compounds • Lewis dot symbols • Ionic compounds and bonding • Lattice Energy • Naming ions and ionic compounds • Covalent bonding and molecules • Naming molecular compounds • Percent composition of compounds • Molar Mass		
	Representing Molecules • The octet rule • Electronegativity and Lewis structures • Drawing Lewis Structures • Formal charges • Resonance • Exceptions to the octet rule		
	Molecular Geometry, Intermolecular Forces, and Bonding Theories • Molecular geometry • Molecular geometry and polarity • Intermolecular forces • Hybridization of atomic orbitals • Hybridization in molecules containing multiple bonds • Molecular orbital theory		
	Chemical Reactions • Chemical equations • Combustion analysis • Calculations with balanced chemical equations • Limiting reactants • Periodic trends in reactivity of the main group elements		

	• General properties of aqueous solutions • Precipitation reactions • Acid-base reactions • Oxidations-reduction reactions • Concentration of solutions • Aqueous reactions and chemical analysis		
	Energy Changes in Chemical Reactions • Energy and energy changes • Introduction to thermodynamics • Enthalpy • Calorimetry • Hess's Laws • Standard Enthalpies of Formation • Bond energy and the stability of covalent molecules		
	Gases • The properties of gases • The kinetic molecular theory of gases • Gas Pressure • The"named" gas laws • The ideal gas equation • Real gases		
	Liquids and Solids • The condensed phases • Properties of liquids • Properties of solids • Phase changes • Phase diagrams • Types of crystalline solids		
	Physical Properties of Solutions • Types of solutions • A molecular view of the solution process • Concentration units • Factors that affect solubility • Colligative Properties		
	Entropy and Free Energy • Entropy • Entropy changes in the system and surroundings • Predicting spontaneity		

	Chemical Equilibrium • The concept of equilibrium • The equilibrium constant • Equilibrium expressions • Chemical equilibrium and free energy • Calculating equilibrium concentrations • Le Chatelier's principle		
	Acids, Bases, and Salts • Acid-base definitions • Molecular structure and acid strength • The acid-base properties of water • The pH and pOH scales • Strong acids and bases • Weak acids, weak bases, and ionization constants • Conjugate acid-base pairs • Diprotic and polyprotic acids • Acid-base properties of salt solutions • Acid-base properties of oxides and hydroxides • Lewis acids and bases		
	Acid-Base Equilibria and Solubility Equilibria • The common ion effect • Buffer solutions • Acid-base titrations • Solubility equilibria • Factors affecting solubility • Separation of ions using differences insolubility		
	Chemical Kinetics • Reactions rates • Collision theory of reaction rates • Dependence of reaction rate on reactant concentrations • Dependence of reactant concentration on time • Dependence of reaction rate on temperature • Reaction mechanisms • Catalysis		

D. Learning Resources

A. References

- Burdge, J.; Overby, J. Chemistry: Atoms First 2nd Edition, Mcgraw-Hill (2014)
- Brown, T.L., LeMay Jr., H.E., Bursten, B.E., Murphy, C.J., Woodward, P.M. (2011) Chemistry – The Central Science, 12th ed., Prentice-Hall International, Inc.
- Chang, R. and Goldsby, K. (2016) *Chemistry*, (12th International Edition), New York: McGraw-Hill.
- Kotz, J.C. and Treichel Jr, P.M., Weaver, G.C. (2012) *Chemistry and Chemical Reactivity*, (8th edition). Australia: Brooks/Cole-Cengage Learning.
- Masterton, W.L. and Hurley, C.N. (2008) *Chemistry: Principle and Reactions*, (6th edition). Canada: Brooks/Cole-Cengage Learning,
- Malone, L.J., Dolter, T.O. with Gentemann, S. (2013) *Basic Chemistry* (9th edition) Hoboken, NJ, Wiley.
- McMurry, J. and Ray, R. C. General Chemistry: Atoms First. Pearson
- Petrucci, R.H. (2011) *General Chemistry: Principles and Modern Applications*, (10th edition) Toronto: Pearson Canada
- Silberberg, M.S. (2013) *Principles of General Chemistry* (3rd edition). New York: McGraw-Hill.
- Tro, N.J. with Neu, D. (2012) *Chemistry in Focus: A Molecular View of our World*, (5th edition). Australia: Brooks/Cole Cengage Learning.
- Whitten, K.W., Davis, R.E., Peck, M.L. and Stanley, G.G. (2013) *Chemistry, 10th ed.* Cengage Learning.
- Zumdahl, S.S., and Zumdahl, S.A. (2012) *Chemistry, An Atoms First Approach* (International Edition), Brooks/Cole Cengage Learning.

PRINCIPLES OF CHEMISTRY LABORATORY

A. Course Details

COURSE NAME	**Principles of Chemistry Laboratory**
COURSE DESCRIPTION	The Principles of Chemistry Laboratory introduces the student to the fundamental techniques and skills needed in the Chemistry laboratory. It emphasizes the formation of proper practices and habits, including laboratory and chemical safety, waste minimization and proper and efficient use of resources, and the preparation of proper laboratory reports.
NUMBER OF UNITS	2 units
Pre-Requisite	One year of high school chemistry

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
perform general chemistry laboratory experiments following specified procedures either individually or as a member of a team		✓	✓	✓	✓		✓			
demonstrate basic chemistry laboratory techniques		✓		✓						
Correctly use common laboratory glassware and equipment to make measurements and perform experiments		✓		✓						
gather, record, organize, and interpret data collected from experiments and use the scientific method to derive conclusions appropriate to the scope and quality of data.		✓		✓			✓		✓	
recognize the limitations of experimental and observational methods; carry out laboratory measurements and calculations using the correct significant figures		✓		✓					✓	
demonstrate safe and responsible practices in the laboratory including handling of materials and waste.				✓		✓				✓
write laboratory reports based on experimental results; dutifully acknowledge sources of information	✓			✓			✓	✓	✓	
apply the principles of ethics and truth in science				✓	✓	✓			✓	

C. Course Outline

The following table lists recommended learning activities and/or experiments for the laboratory courses; however, the first topic on laboratory safety must be taken up before all other lab activities. Various topics may be covered by more than one experiment or activity. The experiments may be timed to match the topics covered in the lecture classes.

Laboratory classes are strongly encouraged to use microscale experiments where applicable. Instructors are also encouraged to explore the Internet for videos and demonstrations of experiments especially those that cannot be easily performed in the lab or where resources and equipment are limited.

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Introduction, Lab Safety and Waste Management	• Lab orientation • Lab policies; proper conduct in the lab • Recording of lab data; lab notebook; integrity in preparing lab reports • Lab safety, proper lab attire • Introduction to common laboratory glassware and materials • Film showing • Use of MSDS • Demonstrations	– Handling chemical reagents and wastes – Safety sign conventions – First aid procedures – Fire and earthquake drills – Proper use of lab notebook
	Measurements	• Density of pure liquids, solids and solutions (e.g. sugar solutions, salt solutions)	– Handling solid and liquid materials – Weighing and measuring volume – Care and manipulation of the balance – Significant figures in measurements and calculations – Reading and recording the meniscus – Cleaning glassware
	Matter and its Properties	• Chemical and physical properties; extensive and intensive properties; chemical and	– Making observations of properties of substances – Techniques of

		physical changes • Separation of mixtures (e.g. chromatography)	separation of mixtures
	Atoms, Molecules and Ions	• Exercises in writing chemical formulas • Exercises in naming compounds	
	Quantum Theory and Structure of Atoms	• Atomic spectra; flame test • • Exercises on writing electronic configuration of elements including ions and anions • Periodicity of Properties of Elements within Groups and Periods	Doing flame test
	Chemical Bonding	• Exercises on writing Lewis structures, formal charges • Making models of molecules with different molecular geometries	
	Stoichiometry	• Determination of empirical formula of selected hydrates • Chemical reactions (e.g. synthesis of alum from recycled aluminum; precipitation reaction of calcium chloride and sodium carbonate; redox reactions) • Volumetric analysis •	– Handling volumetric glassware – Titration – Microscale techniques
	Thermochemistry	• Heats of reaction and solution • Calorimetry (e.g. paper cup calorimetry)	– Calorimetry calculations
	Gases	• Gas effusion experiment (NH3 and HCl)	– Handling glassware – Weighing

		• Molar mass of a volatile liquid • Exercises on preparing graphs using data on gas measurements • Graphical analysis of data from gas measurements •	– Water displacement – Preparing graphs – Interpreting graphs
	Intermolecular Forces and Liquids and Solids	• Phase changes: Temperature behavior during solid-liquid transition • Solubility classification of substances • Making models of the different crystal packing	– Graphical analysis – Testing solubility of substances – Making models –
	Physical Properties of Solutions	• Effect of temperature on the solubility of solids • Conductivity: Electrolytes vs. nonelectrolytes • Colligative properties: boiling point elevation, freezing point depression • Colloids: mayonnaise making; samples of colloids	– Preparation of solutions
	Chemical Equilibrium	• Le Chatelier's Principle: Effect of temperature on equilibrium	– Colorimetry
	Acid-Base Equilibrium	• Approximation of pH of various substances using acid-base indicators • pH measurement • Titration: the molarity of acetic acid in vinegar • Determination of	– Use of pH paper, pH meter, indicators – Titration

		molar mass and Ka for an unknown weak acid	
	Solubility Equilibria	• Determining the acid-base properties of various salts • Properties of buffers	– Testing acidity and basicity – Preparing buffers
	Kinetics	• Rate measurements: iodine clock reaction; iodide-iodate reaction • Determination of rate law; determination of activation energy	– Graphical analysis
	Electrochemistry (optional)	• Redox reactions using microscale	– Use of microscale techniques

D. Learning Resources

A. References

- *Slowinski, E.J., Wosley, W.C. and Rossi, R.. (2011) Chemistry Principles in the Laboratory, 10th ed., Brookes/Cole Cengage Learning.*
- Beran, J.A. (2013) Laboratory Manual for Principles of General Chemistry, 10th ed., John-Wiley& Sons, USA.

B. Online Resources:

http://www.chem.ox.ac.uk/vrchemistry/labintro/newdefault.html. Virtual Experiments, University of Oxford

.

http://www.webelements.com/. WebElements. Site explore key information about the elements throught he periodic table.

http://www.chm.davidson.edu/vce/. Virtual Chemistry Experiments.

http://www.uccs.edu/vgcl/index.html. Virtual General chemistry Laboratories. University of Colorado.

http://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/chemclub-update-virtual-chemistry-simulations.html. Virtual chemistry and simulations. American Chemical Society.

A. Course Details

COURSE NAME	**Inorganic Chemistry 1 and 2**
COURSE DESCRIPTION	These courses are devoted to the study of the principles and trends in the chemistry of the elements and the essentials of structure, bonding, and reactivity of inorganic systems. Topics also include electrochemistry, reduction-oxidation reactions, nuclear chemistry, descriptive chemistry of non-metals and metals, spectroscopy and introduction to selected topics (Bioinorganic, Nanomaterials, Organometallics, and Catalysis).
NUMBER OF UNITS	Inorganic Chemistry 1: 3 units lecture or a combination of 2 units lecture and 1 unit laboratory Inorganic Chemistry 2: 3 units lecture or a combination of 2 units lecture and 1 unit laboratory
Pre-Requisite	Inorganic Chemistry 1 - Principles of Chemistry Inorganic Chemistry 2 – Inorganic Chemistry 1
Co-Requisite	Inorganic Chemistry 2 – Physical Chemistry 1

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Predict the trends and properties of the elements in the periodic table based on current understanding of the atomic structure	✓		✓	✓			✓	✓	✓	
Analyze reactivity of inorganic compounds based on their structure	✓		✓	✓			✓	✓	✓	
Draw generalizations related to structure, properties and reactivity of main group elements	✓		✓	✓			✓	✓	✓	
Derive point groups of simple molecules	✓		✓				✓	✓	✓	
Utilize basic concepts of molecular symmetry and Group Theory to rationalize bonding and structure	✓		✓	✓			✓	✓	✓	

Describe bonding structure and reactivity of coordination compounds and organometallic compounds	✓		✓	✓			✓	✓	✓	
Predict products from given reactants based on different reaction mechanisms of coordination compounds	✓		✓	✓			✓	✓	✓	
Describe solid state chemistry of metals, semiconductors and ionic solids	✓		✓	✓			✓	✓	✓	
Justify spectroscopic properties of coordination compounds based symmetry and point group analysis	✓		✓	✓			✓	✓	✓	
Compare and contrast galvanic and electrolytic electrochemical cells; determine standard and non-standard cell potentials	✓		✓	✓			✓			
Differentiate chemical and nuclear reactions, fission and fusion; calculate binding energy; apply kinetics to radioactive dating	✓		✓	✓			✓	✓		
Defend position on use and development of nuclear energy in the Philippine setting	✓		✓	✓	✓	✓	✓	✓	✓	✓
Able to compose a report on a journal article, inorganic materials indigenous to the Philippines or a reaction paper to a current national issue related to inorganic chemistry	✓		✓	✓	✓	✓	✓	✓	✓	✓

C. Course Outline

Inorganic Chemistry 1

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	• Donor Acceptor Chemistry (Acids and Bases)		• Problem sets • Projects • Abstracts/Reports • Long exam/Quizzes • Models

	• Chemistry of Main Group Elements: Groups 1 and 2		•
	• Chemistry of Main Group Elements: Groups 13 to 18		•
	• Electrochemistry, Oxidation-Reduction Reactions		•
End of Inorganic Chemistry 1			

Inorganic Chemistry 2

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	• Atomic Structure		
	• Valence Bond Theory Molecular Orbital Theory		
	Symmetry and Group Theory		
	• Coordination Chemistry ➢ Structure and Isomers ➢ Bonding theories in Coordination Chemistry ➢ Electronics Spectra • Reactions and Mechanisms		•
	• Nuclear Chemistry	•	• Examination • Presentation by the student • Debate • Reflection paper
	Solid State		
	• Special Introductory Topics in Inorganic Chemistry e.g. ➢ Organometallics ➢ Bioinorganic materials ➢ Nanomaterials ➢ Catalysis and Important Industrial Processes		

D. Learning Resources

A. Journals

- Various journals in Inorganic Chemistry
- Online resources (e.g. Pearson Higher Education. http://wps.pearsoned.co.uk/ema_uk_he_housecroft_inorgchem_2/25/6533/1672555.cw/index.html

B. Textbooks

- Meissler, G.L., Fischer, P.J. and Tarr., D.A. (2014) Inorganic Chemistry, 5th ed. Pearson.
- Housecroft, C.E. and Sharpe, A.G. (2012) Inorganic Chemistry, 4th ed. Pearson.
- Atkins P., Overton T., Rourke J., Weller M., Armstrong F., Hagerman M. (2010) Shriver & Atkins Inorganic Chemistry, 5th ed. W.H. Freeman and Company, New York.
- Huheey, J.E., Keiter, E.A. and Keiter, R.L. (1993) Inorganic Chemistry: Principles of Structure and Reactivity 4th ed. Harper and Row (or latest edition).
- Douglas, McDaniel, and Alexander. (1994) Concepts and Models in InorganicChemistry, 3rd ed. Wiley.
- Cotton, Wilkinson and Gaus. (2002) Basic Inorganic Chemistry, 3rd ed. Wiley.
- Cotton, F.A.; Wilkinson, G. (1999) Advanced Inorganic Chemistry. A Comprehensive Text, 6th ed. Interscience: New York, U.S.A.

INORGANIC CHEMISTRY LABORATORY

A. Course Details

COURSE NAME	**Inorganic Chemistry 1 Laboratory and Inorganic Chemistry 2 Laboratory**
COURSE DESCRIPTION	These courses introduce the student to the techniques and skills needed in an inorganic chemistry laboratory; and are intended to supplement and reinforce the topics presented in the lecture.
NUMBER OF UNITS	Inorganic Chemistry Laboratory 1 - 1 unit Inorganic Chemistry Laboratory 2 – 1 unit
Pre-Requisite	
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
synthesize and characterize inorganic compounds.	✓	✓	✓	✓	✓			✓	✓	
properly operate laboratory instruments safely.		✓		✓	✓	✓		✓	✓	
reinforce theories of chemical bonding and molecular geometry learned earlier with experimental methodology.	✓	✓	✓	✓	✓			✓	✓	
defend experimental results through oral presentations.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
write laboratory reports in the format of a scientific article.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
practice chemical safety and waste minimization, and proper waste handling.	✓		✓	✓	✓			✓	✓	
effectively use primary and secondary sources of chemical information.	✓		✓	✓	✓	✓	✓	✓	✓	✓
relate chemistry with national and international issues (e.g. disaster, environment, etc).	✓		✓	✓		✓	✓	✓	✓	✓
work effectively as a member of a team.					✓	✓				

C. Suggested Experiments/Activities

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Chemistry of Main Group Elements		
	Hard and Soft Acids and Bases		
	Reduction Oxidation Reactions		
	Synthesis and Characterization of Polyiodides		
	Electronic Spectra of Copper(II) Complexes		
	Job's Method of Continuous Variations		
	Complex Iron Salts		

	Syntheses of Tris(oxalato) metallates		
	SchiffBase Complexes of Nickel(II)		
	Oxo-molybdenum Chemistry		
	Microsynthesis of [Fe(acac)3]		
	Modelling Simulation		
	Experiments on Special Topics (e.g. Catalysis, Nanomaterials, Bioinorganic materials, Organometallics)		

D. Learning Resources

A. Text and References

- MIT Open courseware: http://ocw.mit.edu/Ocw
- Journal of Chemical Education
- Tanaka, J. and S.L. Suib. (1999) Experimental Methods in Inorganic Chemistry. Upper Saddle River: Prentice Hall.
- Girolami, G.S., Rauchfuss, T.B. and Angelici, R.J. (1999) Synthesis and Techniques in Inorganic Chemistry. 3rd ed. Sausalito: University Science Books
- Szafran, Z., Pike, R.M., and Singh, M.M. (1991) Microscale Inorganic Chemistry: A Comprehensive Laboratory Experience

ORGANIC CHEMISTRY 1 & 2

A. Course Details

COURSE NAME	**Organic Chemistry 1 & Organic Chemistry 2**
COURSE DESCRIPTION	Basic Organic Chemistry is made up of two semesters of lectures. There are two approaches that may be used: a. By functional groups: The two courses cover the functional groups sequentially in order of increasing complexity. The structure, stereochemistry, nomenclature, chemical properties, reactivity, basic synthesis and spectroscopic analysis of each functional group are covered together. b. Structure and reactivity: The first semester covers organic structure, stereochemistry, nomenclature and spectroscopic analysis, while the second semester shall focus on chemical properties, reactivity and basic synthesis.

	Regardless of the approach, all of the topics should have been covered at the end of two courses.
NUMBER OF UNITS	Organic Chemistry 1: 3 units Organic Chemistry 2: 3 units
Pre-Requisite	Organic Chemistry 1: Principles of Chemistry (Lecture and Laboratory) Organic Chemistry 2: Organic Chemistry 1 Lecture and Laboratory
Co-Requisite	Organic Chemistry 1 Lecture: Organic Chemistry 1 Laboratory Organic Chemistry 2 Lecture: Organic Chemistry 2 Laboratory

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Apply the concepts of organic structural theory to explain and predict the physical properties and chemical reactivity of organic molecules ranging from simple organic compounds to macromolecules and biomolecules.	✓		✓	✓			✓	✓		
Identify organic compounds, give their IUPAC names, and draw the molecular structures of these compounds.	✓		✓	✓			✓	✓		
Use molecular models/softwares for conformational analysis and stereochemical projections of chiral compounds.	✓		✓	✓	✓		✓	✓		
Recognize stereochemical differences, i.e. subtle differences in the three-dimensional structure of organic molecules which affect optical, physical and chemical properties; assign the configuration at each chiral center in an asymmetric molecule.	✓		✓	✓			✓	✓		
Identify the organic starting material, organic product and/or necessary reagents for chemical reactions that are characteristic of the different functional classes of organic compounds.	✓		✓	✓			✓	✓		
Describe the detailed reaction mechanisms of common organic	✓		✓	✓			✓			

reactions.										
Analyze organic reactions using structural, mechanistic, thermodynamic and kinetic considerations.	✓		✓	✓			✓	✓		
Apply chemical methods and spectroscopic techniques such as UV-visible, IR, NMR and MS for the analysis of simple organic compounds.	✓		✓	✓	✓		✓	✓		
Plan strategies for the synthesis of organic compounds from simpler starting materials.	✓		✓	✓	✓		✓	✓		
Demonstrate understanding of chemical safety and waste minimization.	✓			✓		✓	✓			

C. Course Outline

Learning Outcomes	Topic/s	Suggested Learning Activities/ Teaching Strategies	Suggested Assessment
At the end of this course, the students should be able to: a. Draw molecular structures (Lewis, skeletal, condensed), calculate the formal charge/s, and identify the chemical bonds of a molecule. b. Name, draw, and distinguish the different functional groups of organic compounds. c. Predict the products of a reaction as well as to identify reactants needed in order to prepare a particular compound, including the regio- and stereochemical outcomes.	Introduction A. This includes a review of topics in general chemistry that are necessary for the understanding of organic chemistry: a. Atomic structure: carbon and other elements commonly found in organic compounds b. Electron accounting and Lewis structures of organic molecules (including isomeric and resonance structures)	Lectures (Blackboard/ Powerpoint presentation) Concept maps Group discussion	On-line and Written Examinations (includes short quizzes) Homeworks (Individual/Group) Essays/Reports End-chapter problem sets Recitation Problem solving

d. Visualize the three-dimensional shapes of organic molecules using the different standard molecular representations and distinguish constitutional, configurational, and conformational differences. e. Predict the property and reactivity of a molecule based on its shape. f. Draw the mechanisms of a variety of organic reactions: substitution, elimination, addition, free radical reaction. g. Use electronic effects (hyperconjugation, inductive effect, and resonance) and structural effects to predict chemical behaviors of organic compounds and use curved arrows to show the movement of electrons in bond breaking and bond forming processes. h. Propose multiple-step transformations of simple organic molecules i. familiar with organic compounds obtained from local/natural sources	c. Hybridization and the geometry and shape of simple organic molecules ; bond strength d. Intermolecular and intramolecular attractive forces e. Lewis and Brönsted-Lowry acids and bases. B. Additional topics may include functional groups and the classification scheme for organic compounds; a. Types of reactions based on net transformation (substitution, addition, elimination, oxidation and reduction, rearrangement) b. Types of reaction mechanisms, bond cleavage and reactive intermediates c. Reaction energetics.		
	Stereochemistry A. Optical activity and chirality	Lectures (Blackboard/	On-line and Written

	B. Types of configurational isomers (enantiomers, diastereomers, and *meso* compounds), racemic mixtures C. Use of stereochemical drawings (flying wedge, Fischer, Newman and sawhorse projections) D. Molecular configuration (R and S designations) E. Conformations and conformational analysis. F. Relevance to biological activity (e.g. drugs, flavor compounds and agrochemicals) G. Polymer properties	Powerpoint presentation) Concept maps Group discussion	Examinations (includes short quizzes) Homeworks (Individual/Group) Essays/Reports End-chapter problem sets Recitation Problem solving
	Chemistry of the Different Classes of Organic Compounds A. The different classes of organic compounds based on their functionality are enumerated below. Their discussions should include its nomenclature, physical properties, sources, uses, preparation, analysis, reactions, mechanisms, and simple multi-steps synthesis. a. Alkanes, alkenes, alkynes and polyenes	Lectures (Blackboard/ Powerpoint presentation) Concept maps Group discussion	On-line and Written Examinations (includes short quizzes) Homeworks (Individual/Group) Essays/Reports End-chapter problem sets Recitation Problem solving

	b. Alicyclic and cyclic hydrocarbons c. Alkyl halides d. Alcohols, ethers and epoxides e. Carboxylic acids and derivatives f. Aldehydes and ketones g. Benzene and aromatic derivatives h. Phenols i. Amines j. Introduction to Biomolecules: fats, carbohydrates, amino acids and proteins		
	Introduction to Spectroscopy A. UV-visible B. Infrared C. Mass Spectrometry D. Nuclear magnetic resonance	Lectures (Blackboard/ Powerpoint presentation) Concept maps Group discussion	On-line and Written Examinations (includes short quizzes) Homeworks (Individual/Group) Essays/Reports End-chapter problem sets Recitation Problem solving – spectral analyses of unknown
	Introduction to Green Chemistry	Lectures (Blackboard/ Powerpoint presentation) Group discussion	On-line and Written Examinations (includes short quizzes) Homeworks (Individual/Group) Essays/Reports Recitation Problem solving Case study

D. Learning Resources

B. Suggested References

- Klein, D. R. (2015) Organic Chemistry, 2nd Ed. John Wiley & Sons.
- McMurry, J. (2015) Organic Chemistry, 9th Ed., Thomson Learning.
- Brown, W. H., Iverson, B. L., Anslyn, E., and Foote, C. (2013) Organic Chemistry, 7th Ed., Thomson Learning.
- Wade Jr, L.G. (2015) Organic Chemistry, 8th Ed., Prentice Hall.
- Solomons, G., Fryhle, C., and Snyder, S. (2014) Organic Chemistry, 11th Ed., John Wiley & Sons.
- Carey, F. and Guiliano, R. M. (2013) Organic Chemistry, 9th Ed., McGraw Hill Education.
- Brown, W. H. and Poon, T. (2015) Introduction to Organic Chemistry, 6th Ed. John Wiley.
- Loudon, G. M. and Parise, J. (2015) Organic Chemistry, 6th Ed., Oxford University Press, USA
- Silverstein, R., Webster, F. X., Kiemle, D., and Bryce, David (2014) Spectrometric Identification of Organic Compounds 8th Ed., John Wiley.
- Morrison, R. T. and Boyd, R. N. (2014) Organic Chemistry, 7th Package Ed., Prentice Hall College Division.

ORGANIC CHEMISTRY 1 & 2 LABORATORY

A. Course Details

COURSE NAME	**Organic Chemistry 1 Laboratory & Organic Chemistry 2 Laboratory**
COURSE DESCRIPTION	The Organic Chemistry 1 & 2 Laboratory courses equip the student with the basic laboratory procedures and skills of Organic Chemistry. It is concerned with the formation of proper practices and habits, including laboratory and chemical safety, waste minimization and proper and efficient use of resources, and the preparation of proper laboratory reports.
NUMBER OF UNITS	Organic Chemistry 1 Laboratory: 2 units Organic Chemistry 2 Laboratory: 2 units
Pre-Requisite	Organic Chemistry 1 Laboratory: Principles of Chemistry (Lecture and Laboratory) Organic Chemistry 2 Laboratory: Organic Chemistry 1 Lecture and Laboratory
Co-Requisite	Organic Chemistry 1 Laboratory: Organic Chemistry 1 Lecture Organic Chemistry 2 Laboratory: Organic Chemistry 2 Lecture

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Explain the rationale behind the Organic Chemistry experimental procedure: choice of glass wares, solvents, reaction conditions, & equipment for a particular reaction or organic transformation.	✓		✓	✓	✓		✓	✓		
Apply safety precautions in the laboratory.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Demonstrate good logbook keeping – detail record of what is done.	✓	✓		✓		✓	✓		✓	
Synthesize simple organic compounds through the application of organic reactions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Describe the progress of the reaction.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Separate and purify organic compounds.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Analyse and present experimental data.	✓		✓	✓	✓	✓	✓	✓	✓	
Plan and conduct a variety of organic reactions, including safety considerations.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Analyze and identify the structure of simple organic compounds using wet analysis and spectroscopic method.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Properly handle lab chemicals and dispose chemical waste.	✓	✓	✓	✓	✓	✓	✓	✓	✓	

C. Course Outline

Learning Outcomes At the end of the course, the student should be able to:	Topic/s	Suggested Learning Activities/ Teaching Strategies	Suggested Assessment
Organic Chemistry 1 Laboratory			
1. Maintain an appropriate scientific notebook with MSDS information on relevant chemical reagents,	Extraction: Solid-Liquid; Liquid-Liquid	Pre-Lab, Actual Conduct of Experiments, Post-Lab	Quizzes/Long Exams/ Practical Exams/Laboratory Reports/Oral
	Melting Point and Boiling Point Determination		
	Distillation (at least 2 types of set-up): Simple/Fractional or Steam		
	Crystallization		

experimental procedure followed, data and observations made during the experimental process. 2. Engage safe laboratory practices in handling laboratory glassware, equipment, and chemical reagents. 3. Interpret experimental results by connecting the data with the theories learned in class, and draw reasonable conclusions for writing laboratory reports. 4. Determine the limiting reagent and calculate the yield/recovery of a particular reaction. 5. Use information resources in chemistry, including primary literature, tabulated data, online resources, in writing laboratory reports. 6. Perform purification and other simple techniques commonly used in organic chemistry: (A)gravity filtration, (B) suction	Sublimation Chromatography (TLC and Gravity (open column) Functional Group Analysis of Organic Compounds Systematic Identification of Organic Compounds		Reports

filtration, (C)recrystallization, (D) distillation, (E) extraction, (F) reflux, (G) thin layer chromatography. 7. Perform purification and other more advanced techniques commonly used in organic chemistry: (A) column chromatography, (B) rotary evaporation, (C) distillation 8. Perform micro-scale reactions and synthesis of organic compounds and use information learned from Organic Chemistry I and II in multiple step transformation of simple organic molecules. 9. Identify organic compounds through a combination of physico-chemical tests, and spectroscopic analysis.			
Organic Chemistry 2 Laboratory : Synthesis of Organic Molecules			
	Suggested Experiments		
	a. Acid Catalyzed Dehydration of Alcohols Ex. 1. Cyclohexene from Cyclohexanol 2. Pentenes from 2-Pentanol		

	Nucleophilic Substitution Reaction, Second Order Ex. 1. Conversion of 1-Butanol to 1-Bromobutane 2. 1 -Iodohexane from 1-bromohexane		
	Nucleophilic Substitution Reaction, First Order Ex. 1. Conversion of t-Amyl Alcohol to t-Amyl Chloride Using HCl 2. Kinetic Study of the Hydrolysis of t-Butyl Chloride		
	Oxidation Reaction Ex. 1. Oxidation of Heptanal to Heptanoic Acid 2. o-Chlorotoluene to o-Chlorobenzoic Acid		
	Electrophilic Aromatic Substitution Reaction Ex. 1. Nitration of Methyl Benzoate 2. Friedel-Crafts Alkylation of p-Dimethoxybenzene		
	Ester Formation Ex. 1. Synthesis of Aspirin 2. Preparation of Isoamyl Acetate		
	Condensation Reaction Ex. 1. Aldol Condensation of Acetone and Bensaldehyde 2. Claisen Condensation of Ethyl Acetate and Benzaldehyde		
	Multiple Synthesis Ex. Synthesis of Triphenylmethanol by Reaction of Methyl Benzoate and Phenylmagnesium Bromide		
	Biocatalysis		

D. Learning Resources

Suggested references

- Pavia, D.L., Kriz, G. S., Lampman, G. M., and Engel, R. G ( ) A Microscale Approach to Organic Laboratory Techniques 5th Ed. Brookes/Cole Laboratory Series for Organic Chemistry
- Williamson, K. L. and Masters, K. M. (2011) Organic Chemistry Laboratory 6th ed. Cengage Learning
- Vogel, A. I., Tatchell, A. R., Furnis, B. S., Hannaford, A. J. and Smith P. W. G. (1996) Vogel's Textbook of Practical Organic Chemistry , 5th ed. Prentice Hall

ANALYTICAL CHEMISTRY 1

A. Course Details

COURSE NAME	**Analytical Chemistry 1**
COURSE DESCRIPTION	This course is designed to give students an understanding of the principles and practice of gravimetric and volumetric methods, potentiometry and spectrophotometry, analytical measurements and data analysis.
NUMBER OF UNITS	3 units
Pre-Requisite	General Chemistry 2 Lecture and Laboratory
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
demonstrate ability to select and use appropriate instruments and laboratory apparatus to perform measurements of psychical and chemical properties of substances.	✓	✓								
recognize the concepts of stoichiometry: moles, concentrations, dilution, aliquot and apply these to solving problems in quantitative analysis.	✓	✓	✓						✓	

relate charge and mass balance to the concentrations of chemical species in equilibrium.	✓		✓						✓	
apply the concepts of equilibrium constants, ionic equlibria, acitivity, and activity coefficients in solving problems in quantitative analyses in acid –base equilibria, solubility equilibria, complex ion equilibria, and redox equilibria.	✓		✓	✓					✓	
solve problems applying concepts of volumetric analyses acid-base titrations, precipitation titrations, complexometric and redox titrations.	✓	✓	✓	✓					✓	
demonstrate an understanding of the concepts of solubility products and factors affecting solubility and apply these in performing gravimetric analysis.	✓	✓								
demonstrate an understanding of the concepts of potentiometry and apply these potentiometric measurements.	✓	✓	✓	✓					✓	

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	The Analytic Process A. Classification of types of analysis B. Role and importance of analytical chemistry in various aspects of life		

	C. General steps in quantitative analysis		
	Stoichiometry and Chemical Measurements A. Mole concept B. Concentrations (including dilutions) C. Experimental errors D. Basic statistics (accuracy and precision)		
	Gravimetric analysis A. General steps in gravimetric analysis B. Precipitation C. Drying and ignition D. Gravimetric calculations and applications		
	Volumetric analysis A. Precipitation titration and equilibrium (Ksp) B. Acid-base titration and equilibrium (Ki, Kw) C. Complexometric titration and equilibrium D. Redox titrations E. Problem solving F. Applications G. Multi-method analysis (solving problems involving combinations of classical methods of analysis)		
	Potentiometry 1. Quantitation methods in direct potentiometry 2. Potentiometric titration methods 3. Applications		

D. Learning Resources

A. Textbooks
- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).

B. Handbooks
- AOAC on CD-ROM and EURACHEM handbook

C. Journals
- Current analytical chemistry journals

D. References

- Harris, D.C. (2004) Exploring Chemical Analysis 3rd ed., W. H. Freeman.
- Skoog, D.A, Holler, F.J. and Nieman, T.A. (1997) Principles of Instrumental Analysis, 5th ed., Brooks/Cole.
- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).
- Skoog, West, Holler and Crouch. (2000) Analytical Chemistry, An Introduction 7th ed., Saunders College Publishing, New York (or latest edition).
- Skoog, West, Holler and Crouch. (2003) Fundamentals of Analytical Chemistry, 8th ed., Brooks Cole (or latest edition).
- Harvey, D. (2000) Modern Analytical Chemistry, McGraw-Hill, USA.
- Rubinson and Rubinson. (1998) Contemporary Chemical Analysis, Prentice –Hall, NJ.
- Christian, G. (2003) Analytical Chemistry, 6th ed., John Wiley& Sons (or latest edition).

E. Others requirements/ equipment

- Computer aided instruction software package such as Mathcad and Excel.
- Up-to-date laboratory facilities and equipment.

ANALYTICAL CHEMISTRY 2

A. Course Details

COURSE NAME	**Analytical Chemistry 2**
COURSE DESCRIPTION	This lecture course is designed to develop knowledge and skills for analytical separations and instrumental methods of analysis. Emphasis shall be placed on the principles of instrumentation, instrument components, the limitations of measurements, and the selection of appropriate techniques for specific analytical problems.
NUMBER OF UNITS	3 units
Pre-Requisite	Analytical Chemistry 1 Lecture and Laboratory Organic Chemistry 1 Lecture and Laboratory
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
use computers in data acquisition and processing and use available software for data analysis and construction of calibration curves.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
demonstrate understanding of the significance of parameters in a linear regression equation.	✓	✓	✓				✓	✓	✓	
apply statistics in evaluating quality of analytical data.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
demonstrate understanding of the general principles of electroanalytical methods, optical methods and chromatographic methods	✓	✓	✓	✓		✓		✓	✓	
solve problems applying the principles of separation.	✓	✓	✓	✓		✓		✓	✓	
recognize the basic components of instrumentation in electroanalytical methods, molecular spectroscopy, atomic spectroscopy, gas chromatography and liquid chromatography	✓	✓	✓	✓		✓		✓	✓	
demonstrate critical thinking skills in the use of the instrumental techniques, to solve chemical problems.	✓	✓	✓	✓	✓	✓	✓	✓	✓	

C. Course Outline

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Electroanalytical methods A. Coulometry B. Voltammetry **C.** Amperometry		
	Spectroscopic methods A. Fundamental principles B. Absorbance C. Components of instrumentation		

	Molecular spectroscopy A. UV-VIS absorption spectroscopy B. IR absorption spectroscopy C. Fluorescence spectroscopy		
	Atomic spectroscopy A. Atomic absorption spectroscopy B. Emission spectroscopy		
	Analytical separation A. Solvent extraction B. Chromatography C. Efficiency of separation D. D. Band broadening		
	Gas chromatography A. Separation process B. Components of instrumentation C. Applications		
	Liquid chromatography A. Separation process B. Components of instrumentation C. Applications		
	Nuclear and Related Analytical Techniques A. Mass spectrometry B. Nuclear Magnetic Resonance C. X-ray Flouresence D. Radio Analytical		

D. Learning Resources

A. Textbooks
- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).

B. Handbooks
- AOAC on CD-ROM and EURACHEM handbook

C. Journals
- Current analytical chemistry journals

D. References

- Harris, D.C. (2004) Exploring Chemical Analysis 3rd ed., W. H. Freeman.
- Skoog, D.A, Holler, F.J. and Nieman, T.A. (1997) Principles of Instrumental Analysis, 5th ed., Brooks/Cole.
- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).
- Skoog, West, Holler and Crouch. (2000) Analytical Chemistry, An Introduction 7th ed., Saunders College Publishing, New York (or latest edition).
- Skoog, West, Holler and Crouch. (2003) Fundamentals of Analytical Chemistry, 8th ed., Brooks Cole (or latest edition).
- Harvey, D. (2000) Modern Analytical Chemistry, McGraw-Hill, USA.
- Rubinson and Rubinson. (1998) Contemporary Chemical Analysis, Prentice –Hall, NJ.
- Christian, G. (2003) Analytical Chemistry, 6th ed., John Wiley& Sons (or latest edition).

E. Others requirements/ equipment

- Computer aided instruction software package such as Mathcad and Excel.
- Up-to-date laboratory facilities and equipment.

ANALYTICAL CHEMISTRY 3

A. Course Details

COURSE NAME	**Analytical Chemistry 3**
COURSE DESCRIPTION	This course aims to deepen the knowledge and skills in analytical chemistry, particularly in the evaluation and assurance of quality in analytical data. It includes the application of statistics for the evaluation of the results of chemical analysis, as well as the principles and methods of quality assurance applied to the analytical chemistry laboratory. It also presents the principles of sampling and sample preparation, and the principles of calibration.
NUMBER OF UNITS	2 units lecture if combined with 2 units laboratory or 3 units lecture if combined with 1 unit laboratory
Pre-Requisite	Analytical Chemistry 2 Lecture and Laboratory Organic Chemistry 1 Lecture and Laboratory
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
apply statistics in evaluating quality of analytical data.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
discriminate sources and estimate errors and uncertainties in chemical analysis and report analytical results with appropriate significant figures and measurement uncertainty.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
identify appropriate sampling protocols for a particular program of analysis										
interpret and apply the performance characteristics (or figure of merits) of instrumental methods of analysis.	✓	✓	✓	✓		✓	✓	✓	✓	
use computers to construct, evaluate and use correctly calibration curves.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
demonstrate understanding of the significance of parameters in a linear regression equation.	✓	✓	✓				✓	✓	✓	
recognize the need and importance of quality assurance techniques, such as control charts, us of reference materials, recovery test, proficiency testing and method validation						✓		✓	✓	
recognize standard organizations and their requirements for accreditation of testing laboratories.						✓		✓	✓	
demonstrate critical thinking skills in the use of the instrumental techniques, to solve real world chemical problems.	✓	✓	✓	✓	✓	✓	✓	✓	✓	

C. Course Outline

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Statistics of repeated measurements A. Mean and standard deviation B. Normal distribution C. Confidence limits D. Uncertainty		
	Significance testing A. F-test B. T-test C. ANOVA		
	Sampling and sample preparation A. Statistics of sampling: sampling error B. Dissolving the sample C. Sample preparation		
	Calibration methods in instrumental analysis A. Calibration curves B. Linear regression C. Uncertainty in slope, intercept and concentration D. Limit of detection E. Standard addition		
	Quality assurance A. Figures of merit B. Control charts C. Proficiency testing D. Method validation E. Measurement uncertainty estimation		

D. Learning Resources

A. Textbook
- Harris, D.C. Quantitative Chemical Analysis (latest edition)

B. Handbooks
- AOAC on CD-ROM and EURACHEM handbook

C. Journals
- Current analytical chemistry journals

D. Textbooks
- Skoog, West, Holler and Crouch. Analytical Chemistry, An Introduction (latest edition) Saunders College Publishing, New York.
- J.C.Miller and J.N.Miller. Statistics and Chemometrics for Analytical Chemistry (latest edition). Prentice-Hall.
- D. B. Hibbert. Quality Assurance in the Analytical Chemistry Laboratory. (latest edition) Oxford University Press.
- E.Pritchard and V. Barwick . Quality in the Analytical Chemistry Laboratory. (latest edition) John Wiley & Sons.

ANALYTICAL CHEMISTRY 1 LABORATORY

A. Course Details

COURSE NAME	**Analytical Chemistry 1 Laboratory**
COURSE DESCRIPTION	This laboratory course is designed to enable the students to master the basic skills required to perform chemical analysis based on absolute and simple instrumental methods.
NUMBER OF UNITS	2 units
Pre-Requisite	
Co-Requisite	Analytical Chemistry 1 Lecture

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
demonstrate the primary skills for chemical analysis	✓		✓		✓	✓	✓	✓		
recognize the importance of doing replicate testing and calibrated equipment to arrive at statistically valid and accurate results	✓		✓		✓	✓	✓	✓		
perform chemical analysis using absolute and simple potentiometric methods.	✓	✓	✓		✓	✓	✓	✓		

reliably gather, record, analyse and interpret data obtained and draw pertinent conclusions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
write laboratory reports and reference and accredit sources of information correctly.				✓	✓	✓	✓	✓	✓	
relate the properties of chemicals to their safe handling and disposal and interpret safety data information.	✓			✓		✓		✓	✓	
work safely following specified procedures and regulations.	✓			✓	✓	✓	✓	✓	✓	
demonstrate effective time and task management in performing chemical analysis.					✓	✓		✓		
work effectively as a member of a team.					✓	✓	✓	✓		✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Calibration	Calibration of balance and glasswares	
	Statistical Treatment of Data	Replicate weighing of coins	
	Gravimetric Analysis	Determination of sulfate as $BaSO_4$ (or calcium as CaC_2O_4)	
	Acid-Base Titration	Determination of acetic acid in vinegar	
	Complexometric Titration	Determination of water hardness using EDTA	
	Redox Titration	Ddetermination of iodate	
	Potentiometry	Potentiometric titration of strong acid and strong base	

D. Learning Resources

A. References
- Harris, D.C. (2004) Exploring Chemical Analysis 3rd ed., W. H. Freeman.
- Skoog, D.A, Holler, F.J. and Nieman, T.A. (1997) Principles of Instrumental Analysis, 5th ed., Brooks/Cole.

B. Handbooks
- AOAC on CD-ROM and EURACHEM handbook

C. Journals
- Current analytical chemistry journals

D. Textbooks
- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).
- Skoog, West, Holler and Crouch. (2000) Analytical Chemistry, An Introduction 7th ed., Saunders College Publishing, New York (or latest edition).
- Skoog, West, Holler and Crouch. (2003) Fundamentals of Analytical Chemistry, 8th ed., Brooks Cole (or latest edition).
- Harvey, D. (2000) Modern Analytical Chemistry, McGraw-Hill, USA.
- Rubinson and Rubinson. (1998) Contemporary Chemical Analysis, Prentice –Hall, NJ.
- Christian, G. (2003) Analytical Chemistry, 6th ed., John Wiley& Sons (or latest edition).

E. Others requirements/ equipment
- Computer aided instruction software package such as Mathcad and Excel.
- Up-to-date laboratory facilities and equipment.

ANALYTICAL CHEMISTRY 2 LABORATORY

A. Course Details

COURSE NAME	**Analytical Chemistry 2 Laboratory**
COURSE DESCRIPTION	This laboratory course will provide actual practice of modern analytical chemistry. With the exposure of students to the basic techniques of analytical separation and instrumental analysis, they will acquire adequate laboratory skills in the utilization of these analytical tools in real analytical problems.
NUMBER OF UNITS	2 units
Pre-Requisite	
Co-Requisite	Analytical Chemistry 2 Lecture

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
perform chemical analysis using some modern instrumental methods such as chromatography, spectro-scopy and electroanalytical methods.	✓	✓	✓	✓	✓	✓	✓	✓		
Design simple experiments related to the use of other analytical techniques such as microfluidics, digital imaging colorimeter, flow-injection analysis, sensors.	✓	✓	✓	✓	✓	✓	✓	✓		
reliably gather, record, analyze and interpret data obtained and draw pertinent conclusions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
write laboratory reports and reference and accredit sources of information correctly.	✓	✓	✓	✓	✓	✓	✓	✓	✓	
work safely following specified procedures and regulations;.	✓			✓	✓	✓	✓	✓	✓	
demonstrate effective time and task management in performing chemical analysis.					✓	✓		✓		✓
work effectively both as an individual and as a member of a team.					✓	✓		✓		✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Coulometry	Karl Fischer method for moisture determination	
	Potentiometry	Determination of fluoride ion using ion-selective electrode	
	Voltammetry	Voltammetric analysis of Cu(II) ions	
	Amperometry	Determination of DO in water using DO meter	
	Atomic absorption spectroscopy	Detrmination of Pb(II)	
	Atomic emission spectroscopy	Detrmination of potassium	
	Visible spectrophotometry	Measurement of Fe(II)in water using phenanthroline	
	UV spectrophotometry	Determination of caffeine	
	FT-IR spectroscopy	Determination of aromatic hydrocarbons	
	Gas chromatography	Determination of aromatic hydrocarbons	
	Liquid chromatography		
	Integration of instrumental methods	Microfluidics; digital imaging colorimeetry	

D. Learning Resources

A. References

- Harris, D.C. (2004) Exploring Chemical Analysis 3rd ed., W. H. Freeman.
- Skoog, D.A, Holler, F.J. and Nieman, T.A. (1997) Principles of Instrumental Analysis, 5th ed., Brooks/Cole.
- Sawyer, D.T, Heineman, W.R. and Beebe, J.M. (1984) Chemistry Experiments for Instrumental Methods, Wiley

B. Handbooks

- AOAC on CD-ROM and EURACHEM handbook

C. Journals

- Current analytical chemistry journals

D. Textbooks

- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).
- Skoog, West, Holler and Crouch. (2000) Analytical Chemistry, An Introduction 7th ed., Saunders College Publishing, New York (or latest edition).
- Skoog, West, Holler and Crouch. (2003) Fundamentals of Analytical Chemistry, 8th ed., Brooks Cole (or latest edition).
- Harvey, D. (2000) Modern Analytical Chemistry, McGraw-Hill, USA.
- Rubinson and Rubinson. (1998) Contemporary Chemical Analysis, Prentice –Hall, NJ.
- Christian, G. (2003) Analytical Chemistry, 6th ed., John Wiley& Sons (or latest edition).

E. Others requirements/ equipment

- Computer aided instruction software package such as Mathcad and Excel.
- Up-to-date laboratory facilities and equipment.
  - Ion-selective electrodes
  - DO meter / voltammetric analyzer
  - Gas chromatograph or high-pressure liquid chromatography
  - UV-VIS spectrophotometer
  - Karl Fischer titration (optional)
  - Atomic absorption spectrometer

ANALYTICAL CHEMISTRY 3 LABORATORY

A. Course Details

COURSE NAME	**Analytical Chemistry 3 Laboratory**
COURSE DESCRIPTION	This laboratory course will provide experience in the analysis of real samples, including the evaluation of the quality of the results of analysis. It will introduce the students to the techniques of quality assurance.
NUMBER OF UNITS	2 units
Pre-Requisite	Analytical Chemistry 2 Lecture and Laboratory
Co-Requisite	Analytical Chemistry 3 Lecture

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
carry out sampling and sample preparation for the measurement of a chemical parameter on real-world samples	✓	✓	✓	✓	✓	✓	✓	✓		
carry out measurement of a chemical parameter on real-world samples using instrumental methods	✓	✓	✓	✓	✓	✓	✓	✓		
analyze the quality of analytical data and make inferences based on statistical tests	✓	✓	✓	✓	✓	✓	✓	✓	✓	
evaluate the figures of merit of the analysis and infer its fitness for purpose (method validation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	
write laboratory reports and present the results of a chemical analysis properly	✓	✓	✓	✓	✓	✓	✓	✓	✓	
work safely following specified procedures and regulations;.	✓			✓	✓	✓	✓	✓	✓	
demonstrate effective time and task management in performing chemical analysis.					✓	✓		✓		✓
work effectively both as an individual and as a member of a team.					✓	✓		✓		✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Method validation; measurement uncertainty	Analysis of a parameter in a real sample	
	Method comparison	Analysis of a parameter using two methods	
	Sampling	Analysis of an industrial sample	
	Sampling	Analysis of an environmental sample	

D. Learning Resources

E. References

- Harris, D.C. (2004) Exploring Chemical Analysis 3rd ed., W. H. Freeman.
- Skoog, D.A, Holler, F.J. and Nieman, T.A. (1997) Principles of Instrumental Analysis, 5th ed., Brooks/Cole.
- Sawyer, D.T, Heineman, W.R. and Beebe, J.M. (1984) Chemistry Experiments for Instrumental Methods, Wiley

F. Handbooks

- AOAC on CD-ROM and EURACHEM handbook

G. Journals

- Current analytical chemistry journals

H. Textbooks

- Harris, D.C. (2003) Quantitative Chemical Analysis 6th ed., New York. W.H. Freeman & Co. (or latest edition).
- Skoog, West, Holler and Crouch. (2000) Analytical Chemistry, An Introduction 7th ed., Saunders College Publishing, New York (or latest edition).
- Skoog, West, Holler and Crouch. (2003) Fundamentals of Analytical Chemistry, 8th ed., Brooks Cole (or latest edition).
- Harvey, D. (2000) Modern Analytical Chemistry, McGraw-Hill, USA.

- Rubinson and Rubinson. (1998) Contemporary Chemical Analysis, Prentice –Hall, NJ.
- Christian, G. (2003) Analytical Chemistry, 6th ed., John Wiley& Sons (or latest edition).

I. Others requirements/ equipment

- Computer aided instruction software package such as Mathcad and Excel.
- Up-to-date laboratory facilities and equipment.

BIOCHEMISTRY 1

A. Course Details

COURSE NAME	**Biochemistry 1**
COURSE DESCRIPTION	This course covers the structural chemistry of the components of living matter and how this relates to biological function. It also covers the structure-function, kinetics and regulation of biological catalysts.
NUMBER OF UNITS	3 units
Pre-Requisite	Organic Chemistry 2 Lecture and Laboratory Analytical Chemistry 2 Lecture and Laboratory
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
recognize, write formulas, and describe the chemical structures that make up the components of living matter: proteins, carbohydrates, lipids, and nucleic acids	✓			✓			✓	✓		
describe the interactions of these components that give rise to the organized supramolecular structures, cells, and multicellular organisms.	✓			✓			✓	✓		
explain how enzymes work and they are regulated	✓			✓			✓	✓		
explain how chemical reactions are regulated inside living cells	✓			✓			✓	✓		

apply key concepts in biochemistry to explain its practical applications in the field of agriculture, medicine, pharmacy, and allied fields.	✓		✓	✓			✓	✓	✓	
present awareness of major issues at the forefront of biochemistry	✓		✓	✓		✓	✓	✓	✓	
use computers as information and research tools in biochemistry	✓			✓	✓		✓	✓		
evaluate, use, and properly document sources of biochemical information	✓			✓			✓	✓	✓	
to discuss issues and formulate choices as socially responsible chemists in the national and global communities					✓	✓	✓	✓	✓	✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
At the end of this unit, the students are expected to: • Define and differentiate biochemistry from the other branches of chemistry • Differentiate a prokaryotic cell from a eukaryotic cell in terms of its structural features and the organisms in which these cells are found • Identify the organelles found in cells • Give the function of each cell organelle	**Unit 1. Introduction to the cell** A. Definition of Biochemistry B. Overview of the Biomolecules C. The Cell • Types of Cell: Prokaryotic and Eukaryotic • Cell Organelles and Its Functions D. Viruses		

• Identify a virus in terms of its structural features and how it exists			
At the end of this unit, the students are expected to: • Review on the properties of water and buffers particularly the Henderson – Hasselbach equation	**Unit 2. Water: The Solvent for Biochemical Reactions** E. Review on the Properties of Water F. Buffers • Mechanism of Action of Buffers • Choosing a Buffer in the Laboratory • Henderson – Hasselbach Equation • Examples of Buffers in Living Systems		
At the end of this unit, the students are expected to: • Give the name and formula of an amino acid • Classify each amino acid based on: • the structural differences of its side chain (nonpolar, polar uncharged, acidic, and basic) • capacity of the body to synthesize each • Illustrate the amphoteric property of an amino acid • Give the formula of the anion, cation, and zwitterions of an amino acid • Predict the charge of amino acid at a certain pH • Calculate the isoelectric pH • Show the ionization of a given amino acid in a diagram • Identify the chemical	**Unit 3. Structure, function, and properties of amino acids** • Stereochemistry of Amino Acids • Classification of Amino Acids and Its Properties • Amino Acids As Acids and Bases • Titration of Amino Acid • Isoelectric point and Electrophoresis Technique • The Peptide Bond • Formation of a Peptide Bond • Characteristics of the Peptide Bond • Small Peptides with Physiological Activity – Glutathione, Aspartame, Oxytocin, Vasopressin		

reactions which the amino acids undergo and give the products formed in each • Cite some biologically important products of the chemical reactions of amino acids • Define peptide bond • Show how a peptide bond is formed • Describe the chemistry of a peptide bond • Draw the resonance structures of peptide bond • Draw and name structures of polypeptide chains • Identify small peptides with physiological activities			

At the end of this unit, the students are expected to:
• Explain the importance of knowing the primary structure of protein
• Identify and describe the levels of protein structure:
  • primary
  • secondary
  • tertiary
  • quaternary
• Classify proteins according to:
  • biological function
  • shape
  • composition
  • solubility properties
• Illustrate and explain the importance of conformation, exemplified by the relationship between the three dimensional structure of proteins and their
	Unit 4. The Three – Dimensional Structure of Protein
	• Primary Structure of Protein and Its Importance
	• Secondary Structure of Proteins and Its Characteristics
	  • α – helix and β – pleated sheet
	  • Collagen: An Example
	  • Types of Protein Conformation: Fibrous and Globular
	• Tertiary Structure of Proteins and Its		

biological activity
• Explain protein reactivity and function in relation to its structure:
  • native proteins
  • denatured proteins
	Characteristics
	• Forces Involved in Tertiary Structure
	• Myoglobin: An Example
	• Denaturation and Refolding
	• Quaternary Structure of Protein and Its Characteristics
	• Hemoglobin: An Example		

At the end of this unit, the students are expected to:
• Describe the process of differential centrifugation and salting out with ammonium sulfate
• Predict the amino acid sequence of a primary structure of protein
• Identify and describe the different techniques used to extract and purify proteins
	Unit 5. Protein Purification and Characterization Techniques
	• Extraction of Proteins from Cells
	• Column Chromatography
	  • Size – Exclusion Chromatography
	  • Affinity Chromatography
	  • Ion – Exchange Chromatography
	• Electrophoresis
	  • SDS – polyacrylamide Gel Electrophoresis (SDS – PAGE)
	  • Isoelectric Focusing
	• Determining the Primary Structure of Proteins		

At the end of this unit, the students are expected to:
• Describe the chemical nature of enzymes
• Describe the six classes of enzymes based on the type of chemical reactions they catalyze
• Provide the systematic and common name (if any) of an enzyme given a chemical reaction
• Discuss the factors that
	Unit 6. Enzymes
	• Classification and Nomenclature of Enzymes
	• Enzyme – Substrate Binding
	  • Lock – and – Key Model
	  • Induced – Fit Model
	• The Michaelis – Menten Approach to Enzyme Kinetics
	• Enzyme Inhibition		

affect enzyme activity • Illustrate the Michelis-Menten equation • Derive the linear equation of the Lineweaver-Burke Plot from the Michelis-Menten Equation • Discuss the theories behind stereospecificity of enzyme action • Differentiate the types of enzyme inhibitions, namely, competitive, uncompetitive, and noncompetitive • Illustrate the composition of most enzymes with more emphasis on the apoproteins and the coenzymes • Name the coenzymes and their sources • Describe how enzyme inhibitions can be used treat diseases such as Acquired Immunodeficiency Syndrome (AIDS)	• Coenzyme and Apoproteins • Enzyme Inhibition in the Treatment of AIDS		

At the end of this unit, the students are expected to:
• Classify the carbohydrates according to:
  • the number of sugar units
  • the number of carbon atoms
  • the functional group/s present
• Draw the structure of a monosaccharide using both Haworth and Fischer projections
• Diagram the cyclization of monosaccharides which leads to the formation of furan and pyran rings
• Explain the physical properties of carbohydrates based on its structure
• Give the composition and functions of common monosaccharides,
	Unit 7. Carbohydrates
	• Monosaccharides: Their Structures and Stereochemistry
	• Reactions of Monosaccharides
	  • Formation of Glycosides
	  • Oxidation – Reduction Reactions of Sugars
	  • Amino Sugars: An Important Sugar Derivative
	• Important Oligosaccharides: Sucrose, Lactose, Maltose, and Cellobiose
	• Structures and Functions of Polysaccharides: Cellulose, Starch, Glycogen, Chitin, and Bacterial Cell Walls		

disaccharides, and polysaccharides • Enumerate some chemical reactions of carbohydrates • Identify some biologically important monosaccharides, disaccharides, and polysaccharides	• Glycoproteins and Its Role in Immune Response		

At the end of this unit, the students are expected to:
• Define lipids
• Classify lipids as:
  • Saponifiable or non-saponifiable
  • Simple, compound, or derived
• Define and identify fatty acids
• Classify fatty acids as:
  • Saturated or unsaturated
  • Essential or non-essential
• Describe the fatty acids according to their state at room temperature and melting point
• Define triacylglycerols (or triglycerides)
• Classify triacylglycerols (or triglycerides) as simple or mixed
• Draw and name structures of triacylglycerols
• Explain the effect of the fatty acid compositions to the physical state and melting point of triacylglycerols
• Differentiate fats and oils
• Give examples of fats and oils and identify their major triacylglycerol component
• Define waxes and cite their uses
• Draw and name structures of waxes
• Compare and contrast phosphoacylglycerol (or
	Unit 8. Lipids
	• Definition of Lipids
	• Types of Lipids and their Nature
	  • Fatty Acids
	  • Triacylglycerols
	  • Phosphoacylglycerols
	  • Waxes and Sphingolipids
	  • Glycolipids
	  • Leukotrienes and Prostaglandins
	  • Ketone Bodies
	• Biological Membranes: Structure and Compositions
	• Fluid – Mosaic Model of Membrane Structure
	• Mechanism of Transport Across the Membrane
	• Lipid – Soluble Vitamin and Their Functions		

phosphoglycerides) and sphingolipids based on their: • Backbone component • Fatty acid components • Sources • Describe the lipid bilayer and explain their role in biological membrane • Explain why phosphoglycerides are found in lipid bilayer • Enumerate and describe the mechanisms of transport across a membrane • Define glycolipids and illustrate it with a structural formula • Differentiate the lipoproteins according to their density and functions • Define steroids • Identify substances which can be classified as steroids • Differentiate cholesterol and ergosterol • Give the functions of the different sex hormones • Explain the functions of the fat-soluble vitamins • Define prostaglandins, leukotrienes, and ketone bodies • Give the biological functions of prostaglandins and leukotrienes			
At the end of this unit, the students are expected to: • Draw and name the structural formulas of the nitrogenous bases found in DNA and RNA • Show at which point of the bases hydrogen bonding can be formed • Define nucleosides • Draw and name structures of nucleosides • Define nucleotides	**Unit 9. Nucleic Acids: How Structure Conveys Information** • Types of Nucleic Acids: DNA and RNA • Covalent Structure of Polynucleotide • Structure and Component of Nucleotides • Formation of Nucleic Acids from		

• Draw and name structures of nucleotides
• Define nucleic acids
• Compare and contrast DNA and RNA in terms of:
  • nitrogenous bases
  • structures
  • biological functions
  • location in the cell
• Draw a structure of a portion of DNA and RNA
• Describe the Watson and Crick model of a DNA
• Describe the three-dimensional structure of DNA and its denaturation
• Identify and give the function of the different types of RNA
	Nucleotides
	  • Nomenclature of Nucleosides and Nucleotides
	• Structure and Denaturation of DNA
	• The Principal Kinds of RNA and Their Characteristics		

At the end of this unit, the students are expected to:
• State the central dogma
• Describe the characteristics of DNA replication
• Identify the molecular components involved in DNA replication
• Write product of DNA replication, given an oligonucleotide
• Identify the molecular components involved in RNA synthesis
• Write RNA product, given a portion of a DNA strand
• Identify the molecular processes occurring in post-transcriptional modification of RNA
• State and explain the properties of a genetic code
• Describe the general features of the synthesis of proteins
• Identify the molecular components required in protein synthesis
• Describe the stages and biochemical steps of protein
	UNIT 10. The Flow of Genetic Information in the Cell
	• Introduction of the Central Dogma
	• Biosynthesis of Nucleic Acid: Replication
	  • Mechanism of Eukaryotic DNA Replication
	  • DNA Polymerase
	  • Proteins Required for Replication
	  • Proofreading and Repair
	• Transcription of the Genetic Code: The Biosynthesis of RNA
	  • Transcription Mechanism in Eukaryotes
	  • Transcription Regulation
	  • Posttranscriptional RNA Modification
	• Protein Synthesis: Translation of the Genetic Message
	  • The Genetic Code		

synthesis • Define mutation • Identify causes of mutations • Show how mutations can change DNA sequence • Identify cases of mutations and relate them to formation of cancer cells	• Translation Mechanism in Eukaryotes • Posttranslational Modification of Proteins • Protein Degradation • Mutations and Its Agents		
	Introduction to cell G. Cell structure and function H. Compartmentalization I. Cell and tissue specialization		
	Structure and functional groups of biomolecules A. Amino acids and proteins B. Carbohydrates, polysaccharides, and glycoconjugates C. Nucleotides and nucleic acids D. Lipids E. Macromolecular conformation F. Membranes G. Supramolecular assemblies H. Introduction to molecular recognition I. Introduction to techniques for analysis of biological molecules		
	The flow of biological information A. Biochemical unity		

	and introduction to evolution B. The so-called Central Dogma of molecular biology and its modifications C. Basics of gene expression and gene regulation D. Introduction to techniques for gene analysis and manipulation		
	Biological reactions and metabolism A. Biological catalysts B. Introduction to enzyme kinetics C. Allosteric regulation D. Metabolism and regulation E. Bioenergetics		
	Introduction to signal transduction		

D. Learning Resources

A. References

- Karp G (2013) Cell and Molecular Biology: Concepts and Experiments 7th ed., Wiley (or later edition)
- Alberts B, Johnson A, Lewis J (2014) Molecular Biology of the Cell 6th ed., Garland Science (or later edition)
- Lodish H, Berk A, Kaiser CA, Krieger M, Bretcher A, Ploegh H, Amon A, Scott MP (2012) Molecular Cell Biology, 7th ed. W.H. Freeman (or later edition).
- The National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health USA www.pubmed.gov or www.ncbi.nlm.nih.gov
- Virtual models of the biomolecules: http://biomodel.uah.es/en/model3/inicio.htm/
- Biomolecular 3-D structures: http://www.pdb.org and http://www.proteopedia.org

B. Textbooks

- Campbell, M.K. and Farrell, S.O. (2014) Biochemistry, 8th ed., Brooks Cole (or later edition)
- Pratt CW and Cornely K (2013) Essential Biochemistry, 3rd ed., Wiley (or later edition)
- Nelson, D.L. and Cox, M.M. (2012) Lehninger Principles of Biochemistry, 6th ed., W.H. Freeman (or later edition).

- Voet, D. and Voet, J.G. (2010) Biochemistry, 4th ed., John Wiley and Sons (or later edition)
- Berg, J.M. Tymoczko, J.L. , Gatto GJ, and Stryer, L. (2015) Biochemistry, 8th ed., W.H. Freeman (or later edition).
- Mathews, C.K., van Holde, K.E, Appling DR, Anthony-Cahill SJ. (2012) Biochemistry, 4th ed., Benjamin Cummings (or later edition).

BIOCHEMISTRY 2

A. Course Details

COURSE NAME	**Biochemistry 2**
COURSE DESCRIPTION	This course covers the basic chemistry of processes involved in the flow of biological information, the principles of metabolism and the chemistry of the primary metabolic pathways.
NUMBER OF UNITS	3 units
Pre-Requisite	Biochemistry 1
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
explain how living organisms extract energy from the surroundings to perpetuate life	✓			✓			✓	✓		
explain how organisms store and transmit genetic information to grow and to reproduce accurately.	✓			✓			✓	✓		
apply key concepts in biochemistry to explain its practical applications in the field of agriculture, medicine, pharmacy, and allied fields.	✓		✓	✓			✓	✓	✓	
present awareness of major issues at the forefront of biochemistry	✓		✓	✓		✓	✓	✓	✓	
use computers as information and research tools in biochemistry	✓			✓	✓		✓	✓		
list, evaluate, and use primary sources of biochemical information	✓			✓			✓	✓	✓	

to discuss issues and formulate choices as socially responsible chemists in the national and global communities					✓	✓	✓	✓	✓	✓
explain how living organisms extract energy from the surroundings to perpetuate life	✓			✓			✓	✓		

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12, respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
At the end of this unit, the students are expected to: • Appreciate the importance of metabolism • Give an overview of metabolism • Trace the pathway of the digestion of the following basic foodstuffs: • Starch • Fats • Proteins • Identify the digestive juices and the enzymes secreted during the digestion of starch, fats, and proteins • Describe the following: • Action of salivary amylase on starch • Action of the proteolytic enzymes in the stomach • Effect of free HCl in gastric digestion • Action of intestinal enzymes in the completion of digestion • The components of bile and their function in the digestion of fats • Identify the end products of digestion of starch, fats, and proteins • State the role of the end products of digestion in metabolism	**Unit 1. Intermediary Metabolism** • Phases of Metabolism • Anabolism • Catabolism ○ Overview of Metabolism ○ Digestive System and Digestive Juices ○ Hydrolytic Enzymes ○ Stages of Digestion • Salivary digestion • Gastric digestion • Intestinal digestion		

At the end of this unit, the student should be able to: • Define metabolism • Differentiate anabolism and catabolism • Relate metabolism with redox reactions • Give examples of redox reactions occurring in biological systems • Classify biochemical reactions in terms of the six types of chemistry catalyzed by enzymes and occurring in biological cells • Explain the concept of free energy change and the role of ATP in transferring energy from exergonic (energy-producing) processes to endergonic (energy-releasing) processes	**Unit 2. The Importance of Energy Changes and Electron Transfer in Metabolism** • The Nature of Metabolism • The Role of Oxidation and Reduction in Metabolism • Classification of Biochemical Reactions o Oxidation-reduction o Group-transfer o Hydrolysis o Nonhydrolytic cleavage o Isomerization and rearrangement o Bond formation reactions using energy from ATP • Coenzymes in Biologically Important Oxidation-Reduction Reactions • Coupling of Production and Use of Energy		
At the end of this unit, the student should be able to: • Define glycolysis and show its overall reactions • Recall the importance of glucose in biological systems • Identify which organelle in the cell glycolysis occurs • Break down the glycolysis pathway in terms of:	**Unit 3. Glycolysis** • The Overall Pathway of Glycolysis • Conversion of Six-Carbon Glucose to Three- Carbon Glyceraldehyde-3-		

• ATP-requiring steps
• ATP-producing steps
• NAD-involving steps
• Irreversible steps
• Classify the type of biochemical reaction is involved in each step
• Identify the control points in glycolysis
• State the fate of pyruvate during anaerobic metabolism and explain its significance
• Calculate and compare the ATP production in aerobic and anaerobic glycolysis
• Outline the metabolism of other carbohydrates (i.e. dietary carbohydrates and, fructose, galactose, and glycerol) by glycolysis
	Phosphate
	• Glyceraldehyde-3-phosphate is Converted to Pyruvate
	• Anaerobic Metabolism of Pyruvate
	  • Lactate fermentation
	  • Ethanol fermentation
	• Energy Production in Glycolysis (Aerobic and Anaerobic)
	• Entry of Other Carbohydrates into Glycolysis
	  • Dietary carbohydrates (starch, glycogen, maltose, sucrose, lactose)
	  • Fructose, galactose, glycerol		

At the end of this unit, the student should be able to: • Define citric acid cycle • Identify the role of mitochondria in aerobic metabolism • Connect the glycolysis pathway to citric acid cycle • Trace the production of energy and carbon dioxide in the citric acid cycle • Calculate the net gain of ATP molecules produced in the cycle • Identify the end product in the total combustion of glucose and the starting material that enters the citric acid cycle • Give the importance of glyoxylate pathway in plants	**Unit 4. The Citric Acid Cycle** • The Central Role of the Citric Acid Cycle in Metabolism • Overall Pathway of the Citric Acid Cycle • Conversion of Pyruvate to Acetyl-CoA • Individual Reactions of the Citric Acid Cycle • Energetics and		

	Control of the Citric Acid Cycle • The Glyoxylate Cycle: A Related Pathway		
At the end of this unit, the student should be able to: • Define electron transport chain • State the role of electron transport chain in metabolism • Identify the hydrogen acceptors from the metabolite • Differentiate the action of the hydrogen acceptors directly from the metabolite • Identify the electron acceptors and their action on the electrons along the chain • Show the redox reactions occurring in the chain • Give the short forms of the reduced and oxidized states of the hydrogen acceptors • Identify the shuttle systems involved in the transport from cytosol to mitochondria • Describe the mechanism of transport of each shuttle system • Describe the coupling of oxidation to phosphorylation in ATP production • Give the number of molecules of ATP formed from each mole of NAD and FAD • Identify inhibitors that can block the chain	**Unit 5. Electron Transport and Oxidative Phosphorylation** • The Role of Electron Transport in Metabolism • Reduction Potentials in the Electron Transport Chain • Organization of Electron Transport Complexes • The Connection between Electron Transport and Phosphorylation • The Mechanism of Coupling in Oxidative Phosphorylation • Respiratory Inhibitors Used to Study Electron Transport • Shuttle Mechanisms • The ATP Yield from Complete Oxidation of Glucose		

At the end of this unit, the student should be able to:
• Differentiate glycogenesis and glycogenolysis in terms of:
  • utilization of glucose
  • its role in biological systems
  • energy involved
• Outline how glycogenesis and
	Unit 6. Storage Mechanisms and Control in Carbohydrate Metabolism
	• Synthesis and Degradation of Glycogen		

glycogenolysis take place, including the enzymes involved • Explain how glycogen metabolism is controlled, and relate it to diabetes mellitus • Define gluconeogenesis and describe its role in biological systems • Identify smaller biomolecules that can be used to synthesize glucose • Identify the three glycolytic pathways, bypassed in gluconeogenesis • Compare and contrast glycolysis, glycogenesis, glycogenolysis, and gluconeogenesis • Differentiate of pentose phosphate pathway from other carbohydrate metabolic pathways • Identify the importance of pentose phosphate pathway in biological systems • Trace the oxidative and non-oxidative reactions in pentose phosphate pathway • Explain how pentose phosphate pathway is controlled • Relate how a defective enzyme in pentose phosphate pathway can result to hemolytic anemia	(Glycogenesis and Glycogenolysis) • Diabetes mellitus • 6.2 Gluconeogenesis • 6.3 Control of Carbohydrate Metabolism • 6.4 Pentose Phosphate Pathway • Hemolytic Anemia		
At the end of this unit, the student should be able to: • Rationalize how the structure of chloroplast affect photosynthesis • Compare and contrast chlorophyll, hemoglobin, and myoglobin in terms of structure • Trace the ATP production of photosynthesis • Relate photosynthesis with electon transport chain in terms of ATP production • Describe how herbicides can inhibit photosynthesis	**Unit 7. Photosynthesis** • Site of Photosynthesis • Photosystems I and II and the Light Reactions of Photosynthesis • Photosynthesis and ATP Production • Inhibiting Photosynthesis		
At the end of this unit, the student should be able to: • Trace the digestion, transport and storage of triacylglycerols and fatty acids, including the role of the	**Unit 8. Lipid Metabolism** • Catabolism of Lipids: β-oxidation of		

different lipoproteins (HDL, LDL, VLDL) • Identify the hormones involved in the metabolism of dietary triacylglycerols • Calculate the ATP yield in β-oxidation • Identify the end product of β-oxidation • Relate the β-oxidation to citric acid cycle and electron transport chain • Relate the production and significance of ketone bodies to β-oxidation • Trace the biosynthesis of fatty acids, triacylglycerols and cholesterol and identify its control points	fatty acids • The Energy Yield from the Oxidation of Fatty Acids • Catabolism of Unsaturated Fatty Acids and Odd-Carbon Fatty Acids • Ketone Bodies • Fatty Acid Biosynthesis • Synthesis of Acylglycerols and Compound Lipids • Cholesterol Biosynthesis		
At the end of this unit, the student should be able to: • Describe the process of nitrogen fixation • Define transamination reaction • Trace the biosynthesis of the following families of amino acids: • Glutamate family • Aspartate family • Serine family • Pyruvate family • Aromatic family • Histidine family • Explain why glutamate plays a major role in the biosynthesis of amino acids • Differentiate between glucogenic and ketogenic amino acids and give examples of each • Describe the urea cycle and state its importance • Write an equation for the net reaction of the urea cycle • Show how urea cycle is linked to the citric acid cycle	**Unit 9. The Metabolism of Nitrogen** • An Overview of the Metabolism of Nitrogen • Nitrogen Fixation • Amino Acid Biosynthesis • Amino Acid Catabolism • Urea Cycle • Purine Biosynthesis and Catabolism • Pyrimidine Biosynthesis and Catabolism		
At the end of this unit, the student should be able to: • Describe the molecular basis of replication, transcription and	**Unit 10. The Central Dogma** • Replication of DNA		

translation processes • Discuss the flow of genetic information • Discuss gene regulation • Describe the occurrences of Mutagenesis • Identify Xenobiotics	○ Flow of genetic information in the cell ○ Denaturation of DNA • Transcription of RNA • Translation (Synthesis of Proteins) ○ Genetic code ○ Post-translation modification • Xenobiotics • Types of Mutation		
At the end of this unit, the student should be able to: • Describe the steps involved in the purification and detection of nucleic acids • Define restriction endonucleases and state its importance in creating recombinant DNA • Acquire basic knowledge of the process of molecular cloning • Describe the laboratory procedures for the preparation of recombinant DNA • Outline the fundamentals of the polymerase chain reaction and summarize its applications • Identify and appraise the broad scope of biotechnology applications in the market today	**Unit 11. Nucleic Acid Biotechnology Techniques** • Purification and Detection of Nucleic Acids • Cloning and Genetic Engineering • Polymerase Chain Reaction and DNA Fingerprinting • DNA Sequencing		

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
At the end of this unit, the students are expected to: • Define and differentiate biochemistry from the other branches of chemistry • Differentiate a prokaryotic cell from a eukaryotic cell in terms of its structural features and the organisms in which these cells are found • Identify the organelles found in cells • Give the function of each cell organelle • Identify a virus in terms of its structural features and how it exists	**Unit 1. Introduction to the cell** J. Definition of Biochemistry K. Overview of the Biomolecules L. The Cell • Types of Cell: Prokaryotic and Eukaryotic • Cell Organelles and Its Functions M. Viruses		
At the end of this unit, the students are expected to: • Review on the properties of water and buffers particularly the Henderson – Hasselbach equation	**Unit 2. Water: The Solvent for Biochemical Reactions** N. Review on the Properties of Water O. Buffers • Mechanism of Action of Buffers • Choosing a Buffer in the Laboratory • Henderson – Hasselbach Equation • Examples of Buffers in Living Systems		
At the end of this unit, the students are expected to: • Give the name and formula of an amino acid • Classify each amino acid based on: • the structural differences of its side chain (nonpolar, polar uncharged, acidic, and basic) • capacity of the body to synthesize	**Unit 3. Structure, function, and properties of amino acids** • Stereochemistry of Amino Acids • Classification of Amino Acids and Its Properties • Amino Acids As		

each • Illustrate the amphoteric property of an amino acid • Give the formula of the anion, cation, and zwitterions of an amino acid • Predict the charge of amino acid at a certain pH • Calculate the isoelectric pH • Show the ionization of a given amino acid in a diagram • Identify the chemical reactions which the amino acids undergo and give the products formed in each • Cite some biologically important products of the chemical reactions of amino acids • Define peptide bond • Show how a peptide bond is formed • Describe the chemistry of a peptide bond • Draw the resonance structures of peptide bond • Draw and name structures of polypeptide chains • Identify small peptides with physiological activities	Acids and Bases • Titration of Amino Acid • Isoelectric point and Electrophoresis Technique • The Peptide Bond • Formation of a Peptide Bond • Characteristics of the Peptide Bond • Small Peptides with Physiological Activity – Glutathione, Aspartame, Oxytocin, Vasopressin		
At the end of this unit, the students are expected to: • Explain the importance of knowing the primary structure of protein • Identify and describe the levels of protein structure: • primary • secondary • tertiary • quaternary • Classify proteins according to: • biological function • shape • composition • solubility properties • Illustrate and explain the importance of conformation, exemplified by the relationship between the three dimensional structure of proteins and their biological activity • Explain protein reactivity and function in relation to its structure: • native proteins	**Unit 4. The Three – Dimensional Structure of Protein** • Primary Structure of Protein and Its Importance • Secondary Structure of Proteins and Its Characteristics • α – helix and β – pleated sheet • Collagen: An Example • Types of Protein Conformation: Fibrous and Globular • Tertiary Structure of Proteins and Its		

• denatured proteins	Characteristics • Forces Involved in Tertiary Structure • Myoglobin: An Example • Denaturation and Refolding • Quaternary Structure of Protein and Its Characteristics • Hemoglobin: An Example		
At the end of this unit, the students are expected to: • Describe the process of differential centrifugation and salting out with ammonium sulfate • Predict the amino acid sequence of a primary structure of protein • Identify and describe the different techniques used to extract and purify proteins	**Unit 5. Protein Purification and Characterization Techniques** • Extraction of Proteins from Cells • Column Chromatography • Size – Exclusion Chromatography • Affinity Chromatography • Ion – Exchange Chromatography • Electrophoresis • SDS – polyacrylamide Gel Electrophoresis (SDS – PAGE) • Isoelectric Focusing • Determining the Primary Structure of Proteins		
At the end of this unit, the students are expected to: • Describe the chemical nature of enzymes • Describe the six classes of enzymes based on the type of chemical	**Unit 6. Enzymes** • Classification and Nomenclature of Enzymes • Enzyme – Substrate Binding		

reactions they catalyze • Provide the systematic and common name (if any) of an enzyme given a chemical reaction • Discuss the factors that affect enzyme activity • Illustrate the Michelis-Menten equation • Derive the linear equation of the Lineweaver-Burke Plot from the Michelis-Menten Equation • Discuss the theories behind stereospecificity of enzyme action • Differentiate the types of enzyme inhibitions, namely, competitive, uncompetitive, and noncompetitive • Illustrate the composition of most enzymes with more emphasis on the apoproteins and the coenzymes • Name the coenzymes and their sources • Describe how enzyme inhibitions can be used treat diseases such as Acquired Immunodeficiency Syndrome (AIDS)	• Lock – and – Key Model • Induced – Fit Model • The Michaelis – Menten Approach to Enzyme Kinetics • Enzyme Inhibition • Coenzyme and Apoproteins • Enzyme Inhibition in the Treatment of AIDS		
At the end of this unit, the students are expected to: • Classify the carbohydrates according to: • the number of sugar units • the number of carbon atoms • the functional group/s present • Draw the structure of a monosaccharide using both Haworth and Fischer projections • Diagram the cyclization of monosaccharides which leads to the formation of furan and pyran rings • Explain the physical properties of carbohydrates based on its structure • Give the composition and functions of common monosaccharides, disaccharides, and polysaccharides • Enumerate some chemical reactions of carbohydrates • Identify some biologically important monosaccharides, disaccharides, and polysaccharides	**Unit 7. Carbohydrates** • Monosaccharides: Their Structures and Stereochemistry • Reactions of Monosaccharides • Formation of Glycosides • Oxidation – Reduction Reactions of Sugars • Amino Sugars: An Important Sugar Derivative • Important Oligosaccharides: Sucrose, Lactose, Maltose, and Cellobiose • Structures and Functions of Polysaccharides:		

	Cellulose, Starch, Glycogen, Chitin, and Bacterial Cell Walls • Glycoproteins and Its Role in Immune Response		

At the end of this unit, the students are expected to:
• Define lipids
• Classify lipids as:
  • Saponifiable or non-saponifiable
  • Simple, compound, or derived
• Define and identify fatty acids
• Classify fatty acids as:
  • Saturated or unsaturated
  • Essential or non-essential
• Describe the fatty acids according to their state at room temperature and melting point
• Define triacylglycerols (or triglycerides)
• Classify triacylglycerols (or triglycerides) as simple or mixed
• Draw and name structures of triacylglycerols
• Explain the effect of the fatty acid compositions to the physical state and melting point of triacylglycerols
• Differentiate fats and oils
• Give examples of fats and oils and identify their major triacylglycerol component
• Define waxes and cite their uses
• Draw and name structures of waxes
• Compare and contrast phosphoacylglycerol (or phosphoglycerides) and sphingolipids based on their:
  • Backbone component
  • Fatty acid components
  • Sources
• Describe the lipid bilayer and explain their role in biological membrane
• Explain why phosphoglycerides are found in lipid bilayer
• Enumerate and describe the mechanisms of transport across a
	Unit 8. Lipids
	• Definition of Lipids
	• Types of Lipids and their Nature
	  • Fatty Acids
	  • Triacylglycerols
	  • Phosphoacylglycerols
	  • Waxes and Sphingolipids
	  • Glycolipids
	  • Leukotrienes and Prostaglandins
	  • Ketone Bodies
	• Biological Membranes: Structure and Compositions
	• Fluid – Mosaic Model of Membrane Structure
	• Mechanism of Transport Across the Membrane
	• Lipid – Soluble Vitamin and Their Functions		

membrane • Define glycolipids and illustrate it with a structural formula • Differentiate the lipoproteins according to their density and functions • Define steroids • Identify substances which can be classified as steroids • Differentiate cholesterol and ergosterol • Give the functions of the different sex hormones • Explain the functions of the fat-soluble vitamins • Define prostaglandins, leukotrienes, and ketone bodies • Give the biological functions of prostaglandins and leukotrienes			

At the end of this unit, the students are expected to:
• Draw and name the structural formulas of the nitrogenous bases found in DNA and RNA
• Show at which point of the bases hydrogen bonding can be formed
• Define nucleosides
• Draw and name structures of nucleosides
• Define nucleotides
• Draw and name structures of nucleotides
• Define nucleic acids
• Compare and contrast DNA and RNA in terms of:
  • nitrogenous bases
  • structures
  • biological functions
  • location in the cell
• Draw a structure of a portion of DNA and RNA
• Describe the Watson and Crick model of a DNA
• Describe the three-dimensional structure of DNA and its denaturation
• Identify and give the function of the different types of RNA
	Unit 9. Nucleic Acids: How Structure Conveys Information
	• Types of Nucleic Acids: DNA and RNA
	• Covalent Structure of Polynucleotide
	  • Structure and Component of Nucleotides
	  • Formation of Nucleic Acids from Nucleotides
	  • Nomenclature of Nucleosides and Nucleotides
	• Structure and Denaturation of DNA
	• The Principal Kinds of RNA and Their Characteristics		

At the end of this unit, the students are expected to:
• State the central dogma
• Describe the characteristics of DNA replication
• Identify the molecular components involved in DNA replication
• Write product of DNA replication, given an oligonucleotide
• Identify the molecular components involved in RNA synthesis
• Write RNA product, given a portion of a DNA strand
• Identify the molecular processes occurring in post-transcriptional modification of RNA
• State and explain the properties of a genetic code
• Describe the general features of the synthesis of proteins
• Identify the molecular components required in protein synthesis
• Describe the stages and biochemical steps of protein synthesis
• Define mutation
• Identify causes of mutations
• Show how mutations can change DNA sequence
• Identify cases of mutations and relate them to formation of cancer cells
	UNIT 10. The Flow of Genetic Information in the Cell
	• Introduction of the Central Dogma
	• Biosynthesis of Nucleic Acid: Replication
	  • Mechanism of Eukaryotic DNA Replication
	  • DNA Polymerase
	  • Proteins Required for Replication
	  • Proofreading and Repair
	• Transcription of the Genetic Code: The Biosynthesis of RNA
	  • Transcription Mechanism in Eukaryotes
	  • Transcription Regulation
	  • Posttranscriptional RNA Modification
	• Protein Synthesis: Translation of the Genetic Message
	  • The Genetic Code
	  • Translation Mechanism in Eukaryotes
	  • Posttranslational Modification of Proteins
	  • Protein Degradation
	• Mutations and Its Agents		

At the end of this unit, the student should be able to: • Describe the steps involved in the purification and detection of nucleic acids	**Unit 11. Nucleic Acid Biotechnology Techniques** • Purification and Detection of Nucleic		

• Define restriction endonucleases and state its importance in creating recombinant DNA • Acquire basic knowledge of the process of molecular cloning • Describe the laboratory procedures for the preparation of recombinant DNA • Outline the fundamentals of the polymerase chain reaction and summarize its applications Identify and appraise the broad scope of biotechnology applications in the market today	Acids • Cloning and Genetic Engineering • Polymerase Chain Reaction and DNA Fingerprinting DNA Sequencing		

E. Learning Resources

A. References

- Karp G (2013) Cell and Molecular Biology: Concepts and Experiments 7th ed., Wiley (or later edition)
- Alberts B, Johnson A, Lewis J (2014) Molecular Biology of the Cell 6th ed., Garland Science (or later edition)
- Lodish H, Berk A, Kaiser CA, Krieger M, Bretcher A, Ploegh H, Amon A, Scott MP (2012) Molecular Cell Biology, 7th ed. W.H. Freeman (or later edition).
- The National Center for Biotechnology Information, National Library of Medicine, National Institutes of Health USA www.pubmed.gov or www.ncbi.nlm.nih.gov

B. Textbooks

- Campbell, M.K. and Farrell, S.O. (2014) Biochemistry, 8th ed., Brooks Cole (or later edition)
- Pratt CW and Cornely K (2013) Essential Biochemistry, 3rd ed., Wiley (or later edition)
- Nelson, D.L. and Cox, M.M. (2012) Lehninger Principles of Biochemistry, 6th ed., W.H. Freeman (or later edition).
- Voet, D. and Voet, J.G. (2010) Biochemistry, 4th ed., John Wiley and Sons (or later edition)
- Berg, J.M. Tymoczko, J.L. , Gatto GJ, and Stryer, L. (2015) Biochemistry, 8th ed., W.H. Freeman (or later edition).
- Mathews, C.K., van Holde, K.E, Appling DR, Anthony-Cahill SJ. (2012) Biochemistry, 4th ed., Benjamin Cummings (or later edition).

BIOCHEMISTRY LABORATORY

A. Course Details

COURSE NAME	**Biochemistry Laboratory**
COURSE DESCRIPTION	This laboratory course will introduce the students to common skills and techniques needed to perform biochemical investigations. It aims to provide a guide to the students in correlating certain principles of biochemistry with experimental facts.
NUMBER OF UNITS	2 units total (may be split into 1 unit per semester, or a 2-unit, 1 semester lab)
Pre-Requisite	Analytical Chemistry 1 Laboratory
Co-Requisite	Biochemistry (Lecture)

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
describe the isolation and characterization of biomolecules such as carbohydrates, proteins, lipids and nucleic acids.	✓	✓	✓	✓	✓		✓	✓	✓	
analyze simple biochemical compounds.	✓		✓	✓	✓		✓	✓	✓	
apply safety precautions in the laboratory.	✓			✓		✓	✓			
dispose of wastes safely and in compliance with regulations										

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12 respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
At the end of this unit, the student should be able to: • perform simple protein isolation procedures • characterize their sample and describe its properties	Proteins	Laboratory exercise on protein isolation and protein properties	
At the end of this unit, the student should be able to: • measure enzyme activity • examine how different conditions affect enzyme activity	Enzymes	Laboratory exercise on enzyme properties and kinetics	
At the end of this unit, the student should be able to: • characterize carbohydrate samples and describe their properties	Carbohydrates	Laboratory exercise on carbohydrate properties	
At the end of this unit, the student should be able to: • characterize lipid samples and describe their properties	Lipids	Laboratory exercise on lipid properties	
At the end of this unit, the student should be able to: • isolate DNA and characterize the sample	Nucleic acids	Laboratory exercise on nucleic acid isolation and properties	
At the end of this unit, the student should be able to: • Search Internet databases for scientific literature and biomolecular sequence and related information • Visualize biomolecular 3-D structure using Internet tools	Bioinformatics	Computer laboratory exercises on biomolecular databases and tools	

D. Learning Resources

A. Laboratory Manual

- Bernas, G., Ysrael, M., & Bernaldez, A. (1994) Basic Laboratory Studies in Biochemistry, 3rd ed., UST Printing Office.
- Boyer, R.F. (1986) Modern Experimental Biochemistry. Addison-Wesley Publishing Company
- Dryer, R.L. and Lata, G.F. (1989) Experimental Biochemistry. Oxford University Press, Inc.,
- Sambrook, J. and Russell, D.W. (2001) Molecular Cloning, 3rd ed., Cold Spring Harbor Laboratory Press (or later edition). Companion site at www.MolecularCloning.com

B. Others

- Laboratory manual(s) developed for the course(s).
- MIT Open courseware: http://ocw.mit.edu/Ocw
- Virtual models of the biomolecules: http://biomodel.uah.es/en/model3/inicio.htm/
- Virtual lab (ELISA, bacterial identification by PCR and DNA sequencing, etc.): http://www.hhmi.org/biointeractive
- Biomolecular 3-D structures: http://www.pdb.org and http://www.proteopedia.org
- For the computer lab sessions, other key resources are the National Center for Biotechnology Information (www.pubmed.gov or www.ncbi.nlm.nih.gov), the European Bioinformatics Institute (www.expasy.org), and many others.

PHYSICAL CHEMISTRY I

A. Course Details

COURSE NAME	**Physical Chemistry I**
COURSE DESCRIPTION	This course provides the foundations in chemical thermodynamics, physical and chemical equilibria, and an introduction to statistical thermodynamics.
NUMBER OF UNITS	3 units
Pre-Requisite	Organic Chemistry 1 Lecture and Laboratory Analytical Chemistry 1 Lecture and Laboratory Integral Calculus
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
describe, both qualitatively and quantitatively, and explain the behavior of gases.	✓	✓	✓	✓	✓		✓	✓	✓	✓
discuss the three laws of thermodynamics, derive the relevant mathematical expressions and apply them in problem solving.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
explain the significance of the different thermodynamic function and apply them in explaining the equilibrium properties of physical and chemical systems.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
discuss the thermodynamics of phase equilibria and describe their behavior through mathematical expressions.	✓	✓	✓	✓	✓		✓	✓	✓	✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12 respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Ideal gas laws		
	Thermodynamics: Introduction		
	First law of thermodynamics: basic functions and application to ideal gases; thermochemistry		

	2nd law of thermodynamics: Entropy, Gibbs energy; calculation and application		
	Chemical equilibrium; Gibbs energy and equilibrium constant; equilibrium calculations		
	Phase equilibrium – one component systems; ideal solutions; colligative properties of ideal dilute solutions		

D. Learning Resources

Latest editions of the following:

- P. W. Atkins, J. de Paula. Physical Chemistry. Oxford University Press.
- I. Levine. Physical Chemistry. McGraw-Hill Company.
- K. Laidler. Physical Chemistry. Houghton Mifflin Company.
- R. J. Silbey, R. A. Alberty andM. G. Bawendi. Physical Chemistry. John Wiley.

PHYSICAL CHEMISTRY 2

A. Course Details

COURSE NAME	**Physical Chemistry 2**
COURSE DESCRIPTION	This course is a continuation of Physical Chemistry 1. It covers the application of chemical thermodynamics to physical and chemical equilibrium systems, electrochemistry, transport properties, chemical kinetics and surface chemistry.
NUMBER OF UNITS	3 units
Pre-Requisite	Physical Chemistry 1 Lecture
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
describe the behavior and properties of electrolytes and electrochemical systems, both in a qualitative and quantitative way, and calculate the properties of these systems.	✓	✓	✓	✓	✓		✓	✓	✓	✓
explain and predict the kinetics of simple reaction systems of different orders and of complex reactions and carry out calculations based on the principles involved.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
describe and explain surface phenomena in terms of equilibrium and dynamic properties	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12 respectively.

.Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Leaning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Equilibrium electrochemistry		
	Kinetic molecular theory; transport properties of gases and liquids		
	Solutions of electrolytes; transport properties of ions and their applications; equilibrium properties, ionic theories		
	Chemical kinetics: rate laws, Arrhenius equation; mechanisms and		

	applications to enzyme catalysis and photochemical reactions; theories of elementary reactions		
	Surface chemistry: macromolecules and colloids: thermodynamic properties; surface tension measurements; adsorption isotherms; heterogeneous kinetics; size, shape and molar mass of macromolecules; properties of colloids and applications		
	Equilibrium electrochemistry		

D. Learning Resources

Latest editions of the following:

- P. W. Atkins, J. de Paula. Physical Chemistry. Oxford University Press.
- I. Levine. Physical Chemistry. McGraw-Hill Company.
- K. Laidler. Physical Chemistry. Houghton Mifflin Company.
- R. J. Silbey, R. A. Alberty andM. G. Bawendi. Physical Chemistry. John Wiley.

PHYSICAL CHEMISTRY 3

A. Course Details

COURSE NAME	**Physical Chemistry 3**
COURSE DESCRIPTION	This course presents a rigorous introduction to the basic principles of quantum mechanics and its applications. It focuses on a conceptual understanding of quantum theory and the application of these and related concepts to solve chemical problems
NUMBER OF UNITS	3 units
Pre-Requisite	Physical Chemistry 1
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
discuss the background and formalism of quantum mechanics.	✓		✓	✓	✓		✓	✓	✓	
apply the formalism of quantum mechanics to simple systems and relate the results to chemical systems.	✓		✓	✓	✓		✓	✓	✓	
construct the wave functions for one-electron and many-electron atoms	✓		✓	✓	✓		✓	✓	✓	
solve problems in atomic and molecular spectroscopy.	✓	✓	✓	✓	✓		✓	✓	✓	
apply the fundamental concepts of statistical thermodynamics to simple systems.	✓	✓	✓	✓	✓		✓	✓	✓	

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12 respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Background of quantum mechanics; formalism of quantum mechanics		
	Operators, eigenvalue problems, postulates of quantum mechanics and application to simple systems.		
	Exactly soluble problems in one, two and three dimensions.		

	Approximate methods and applications to atoms and molecules.		
	Vibrational and rotational spectroscopy.		
	Statistical thermodynamics: canonical ensembles and partition functions; application of results of quantum chemistry to calculate thermodynamic quantities		

D. Learning Resources

Latest editions of the following:

- P. W. Atkins. Molecular Quantum Mechanics. Oxford University Press.
- P. W. Atkins, J. de Paula. Physical Chemistry. Oxford University Press.
- I. Levine. Physical Chemistry. McGraw-Hill Company.
- K. Laidler. Physical Chemistry. Houghton Mifflin Company.
- D.A. McQuarrie. Quantum Chemisstry. University Science Books.
- R. J. Silbey, R. A. Alberty andM. G. Bawendi. Physical Chemistry. John Wiley, 2005.

PHYSICAL CHEMISTRY LABORATORY 1 AND 2

A. Course Details

COURSE NAME	**Physical Chemistry Laboratory 1 and 2**
COURSE DESCRIPTION	The laboratory courses equips the students with the techniques for evaluating physical properties of chemical systems described in the accompanying lecture.
NUMBER OF UNITS (Lec/Lab)	4 units
Pre-Requisite	Organic Chemistry Laboratory, Analytical Chemistry 1 Laboratory.
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
apply physical methods to characterize the systems at equilibrium.	✓	✓	✓	✓	✓		✓	✓	✓	
apply physical and chemical methods to characterize chemical reactions.	✓	✓	✓	✓	✓		✓	✓	✓	
relate experimental results to models for chemical systems.	✓	✓	✓	✓	✓		✓	✓	✓	

C. Course Outline

A suggested format for the course outline is provided below. The learning outcomes can be derived from the course outcomes.

The possible modes of delivery and assessment are listed in Article V, Section 11 and 12 respectively.

Note: (a) Intended Learning Outcomes; (b) Teaching Strategies; & (c) Assessment Evaluation are to be completed by the instructor.

Learning Outcomes	Topic/s	Learning Activities/ Teaching Strategies	Assessment
	Ideal gas		
	Real gas		
	Thermochemistry		
	Phase equilibria: one-compnent system; two-component system; three component system		
	Partial molar properties		
	Colligative properties		
	Electrochemistry		
	Transport properties		
	Chemical kinetics: order of a reaction; temperature effects		

	Surface properties		
	Spectroscopy and molecular structure		
	Electronic spectroscopy		
	Vibrational and rotational spectroscopy		
	Molecular modeling		

D. Learning Resources

Latest editions of the following:

- A. M. Halpern and J. H. Reeves. Experimental Physical Chemistry – A Laboratory Textbook. Scott, Foresman and Co.
- D. P. Schoemaker, C. W. Garland and J.W. Nibler. Experiments in Physical Chemistry. McGraw-Hill.
- F. A. Bettelheim. Expeerimental Physical Chemistry. W. B. Saundeers.
- R. J. Sime. Physical Chemistry: Methods, Techniques and Experiments. Saunders College Publications.

THESIS

A. Course Details

COURSE NAME	**Thesis**
COURSE DESCRIPTION	Independent active research to be conducted under the guidance of a senior faculty adviser or mentor; the topic may be basic, applied or theoretical in nature.
NUMBER OF UNITS (Lec/Lab)	Undergraduate Thesis 1: 1-3 units Undergraduate Thesis 2: 1-3 units
Pre-Requisite	Level 3 Chemistry Laboratory series; This is a 4th year level course and the student must have completed most of the core Chemistry courses.
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Integrate and apply learnings from previous courses.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Survey current scientific literature.	✓	✓	✓	✓				✓	✓	
Conduct independent study of a particular topic.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Evaluate, interpret and synthesize data and information.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write a scientific document.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Practice responsible conduct of research to include safety, ethics, and respect for intellectual property.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C. Learning Resources

A. Recommendations

- Regular supervision by, and consultations with the adviser are essential. The adviser should pay careful attention to the conduct of the experiments or calculations and the interpretation of results.
- The supervisor should carefully evaluate data quality, progress reports and thesis manuscripts. The output can be presented in conferences, and if appropriate, publication in a peer-reviewed journal.
- The adviser should emphasize and practice research ethics.
- The university should have an intellectual property (IP) policy which covers patentable inventions, devices, etc. The IP rights of the student and faculty adviser should be protected.

B. References

- Kanare, H.M. (1985) Writing the Laboratory Notebook, American Chemical Society, Washington, DC.
- Dodd, J. S. (Ed) (1997) The ACS Style Guide, American Chemical Society, Washington, DC.
- Cain, B. E. (1988) The Basics of Technical Communicating, ACS Professional Reference Book American Chemical Society, Washington, DC.
- There are a number of references which are available on ethics. Some examples include: Chemist's Code of Conduct (American Chemical Society, http://www.chemistry.org), and Ethics in Science (Prof. H. Bauer, http://www.chem.vt.edu).

C. Comments

This course assumes the availability of instrumentation, facilities, chemicals, and other materials needed for research.

PROFESSIONAL ENGAGEMENT

A. Course Details

COURSE NAME	**Professional Engagement**
COURSE DESCRIPTION	This will enable the student to obtain experience in the practice and/or application of chemistry in various settings such as private, government, industry and academe laboratories, research institutions, scientific organizations, and policy making bodies. Through this experience, students will acquire additional skills and insights on the application of chemistry in solving real-world problems. It will also strengthen the link between the study and practice of chemistry.
NUMBER OF UNITS (Lec/Lab)	0-3 units (at least 200 hours)
Pre-Requisite	Level 3 Chemistry Laboratory series; This is a 4th year level course and the student must have completed most of the core Chemistry courses.
Co-Requisite	

B. Course Outcome and Relationship to Program Outcome

COURSE OUTCOMES	PROGRAM OUTCOME									
	A	B	C	D	E	F	G	H	I	J
At the end of this course, the students should be able to:										
Integrate and apply chemistry concepts and skills in the workplace.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Work harmoniously in a workplace environment.			✓	✓	✓	✓	✓		✓	✓
Evaluate, interpret and synthesize data and information.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Communicate effectively both in writing and orally.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Practice responsible conduct in the workplace to include safety, ethics, and respect for intellectual property.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C. Learning Resources

None