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Introduction of Universal Curriculum about "Chemical Separation Methods" Course for Master in Analytical Chemistry

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Abstract
The aim of this study was to compare the curriculum (objectives and contents) of chemical separation methods course in graduate level between Iran and other universities in the world. Besides the offering a full curriculum for this course is the goal of the research. This course is one of the fundamental course for master students in analytical chemistry. This study is applied, descriptive and library research. The population were the syllabuses of this course in graduate level in all universities. 38 universities were selected mainly in the United States of America, England and India using accessible sampling methods. The research tool was a researcher made table included objectives and contents. Results showed a much variety in course syllabus at different countries. Most topics taught in this universities are: gas chromatography; high performance liquid chromatography; thin layer chromatography; gel permeation chromatography; size exclusion chromatography; GC-MS; LC-MS; electrophoresis; capillary electrophoresis; liquid-liquid extraction; solid phase extraction; distillation; crystallization; dialysis and reverse osmosis. Finally Researchers proposed a universal syllabus for this course, included: gas chromatography, filtration methods, advanced techniques of extraction, electrophoresis, capillary electrophoresis and electrochromatography, size exclusion chromatography, supercritical fluids chromatography, high-performance liquid chromatography, thin layer, planer and column chromatography, distillation, hyphenated techniques, crystallization, gel permeation chromatography.
Keywords: Syllabus, Separation, Analytical Chemistry, Graduate, Global.

Introduction

Analytical chemistry is the study of the separation, identification, and quantification of the chemical components of natural and artificial materials *(Holler, F., 1996)*. Qualitative analysis gives an indication of the identity of the chemical in the sample, and quantitative analysis determines the amount of certain components in the substance. The separation of components is often performed prior to analysis. Analytical chemistry has been important since the early days of chemistry, providing methods for determining which elements and chemicals are present in the object in question. During this period significant contributions to analytical chemistry include the development of systematic elemental analysis by Justus von Liebig and systematized organic analysis based on the specific reactions of functional groups. Most of the major developments in analytical chemistry take place after 1900. During this period instrumental analysis becomes progressively dominant in the field. In particular many of the basic spectroscopic and spectrometric techniques were discovered in the early 20th century and refined in the late 20th century *(Wikipedia, 2016)*.

Separation is the all of process and analytical techniques used for substance to divide into its components. There are a large number of important applications in fields such as medicine and manufacturing. The separation sciences follow a similar time line of development and also become increasingly transformed into high performance instruments (Bartle, Keith D.; Myers, Peter, 2002). In the 1970s many of these techniques began to be used together to achieve a complete characterization of samples.

Such processes start with a sample in a mixed state (composed of more than one substance) and transform it into new samples, each of which- in the ideal case-consists of a single substance. Separation methods, then, can be defined as processes that change the relative amounts of substances in a mixture. In chemical methods, one may start with a completely homogeneous mixture (a solution) or a heterogeneous sample (e.g., solid plus liquid); in the act of separation, some particles are either partially or totally removed from the sample.

Since ancient times, people have used methods of separating and purifying chemical substances for improving the quality of life. The extraction of metals from ores and of medicines from plants is older than recorded history. In the middle Ages the alchemists' search for the philosophers' stone (a means of changing base metals into gold) and the elixir of life (a substance that would perpetuate youth) depended on separations. In the industrial and technological revolutions, separations and purifications have assumed major importance. During World War II, for example, one of the main problems of the Manhattan Project, the U.S. government research project that led to the first atomic bombs, was the separation of uranium-235 from uranium-238. Many industries now find separations indispensable: the petroleum industry separates crude oil into products used as fuels, lubricants, and chemical raw materials; the pharmaceutical industry separates and purifies natural and synthetic drugs to meet health needs; and the mining industry is based on the separation and purification of metals. Separations and purifications also find their places in medicine and the sciences. In the life sciences, many advances can be directly traced to the development of each new separation method.

There are two general reasons for performing separations on mixtures. First, the mixture may contain some substance that should be isolated from the rest of the mixture: this process of isolating and thus removing substances considered to be contaminants is called purification. For example, in the manufacture of synthetic drugs, mixtures containing variable proportions of several compounds usually arise. The removal of the desired drug from the rest of the mixture is important if the product is to have uniform potency and is to be free of other components that may be dangerous to the body. The second reason for performing separations is to alter the composition of a sample so that one or more of the components can be analyzed. For example, the analysis of air to assess the quality of the air is of great interest, yet many of the pollutants are at a concentration too low for direct analysis, even with the most sensitive devices. Pollutants can be collected by passing samples of air through a tube containing an adsorbent material. By this process the pollutants are concentrated to a level such that straightforward analysis and monitoring can take place. In a second example, several impurities in a sample may interfere with the analysis of the substance of primary interest. Thus, in the analysis of trace concentrations of metals in rivers, organic substances can cause erroneous results. These interferences must be removed prior to the analysis. Several techniques for removing interferences are discussed in analysis: Interference removal.

Curriculum: During the 1980s critiques of American higher education were increasing in frequency and stridence. Reports such as *A Nation at Risk* (1983) and *Integrity in the College Curriculum* (1985) underscored the need for reform, citing a lack of accessibility, quality, and coherence. Thus During the last decade of the twentieth century, significant changes occurred in American higher education. There are different definitions and interpretations of the term curriculum in addition to variations in approaches to curriculum design. The term *curriculum*, broadly defined, includes goals for student learning (skills, knowledge and attitudes); content (the subject matter in which learning experiences are embedded); sequence (the order in which concepts are presented); learners; instructional methods and activities; instructional resources (materials and settings); evaluation (methods used to assess student learning as a result of these experiences); and adjustments to teaching and learning processes, based on experience and evaluation. Although the term *curriculum* is variably used, this definition is sufficiently inclusive and dynamic to account for the many innovations in the undergraduate curriculum that involve instructional methods, sequencing, and assessments as well as instructional goals and content, all of which have been implemented in order to improve learning (webcorp.org, 2016). During its short life, the concept of curriculum has beard several changes. Curriculum is a set of opportunities for learners to get engaged with other individuals, and things in specific time and place (Forouzan Tonkaboni, et. al., 2014).

The role of curriculum in higher education is sine quo non for the provision of quality and relevant educational programs and services to the current and potential learners in the USA and elsewhere in the world. Regardless of sizes, types or origins, curriculum is considered the heart and soul of all educational institutions. Curriculum is crucial for the well-being and effectiveness of higher education (Barnett, R., & Coate, K, 2005) both in the short and long-term (Mohammad Ayub Khan1 & Laurie Smith Law, 2015)

Curriculum is the foundation of the teaching-learning process. It involves developing programs of study (study plans), teaching strategies, resources allocations, specific lesson plans and assessment of students, and faculty development (Education, 2012). Given these

realities the approach to developing curriculum in higher education institutions is and should be a prime concern for all stakeholders, especially for educators, policy-makers, government, parents and the society at large (Alberta Education, 2012). Moreover, there is a growing need for higher education institutions to respond to the changing environment in a positive and learner-centered manner through quality curriculum. For example, the competence-based curriculum produces graduates who are better prepared for their future management tasks. Students who have learned to adapt to change and to adapt their abilities to a variety of contexts and situations, Develop managerial competencies for a turbulent world (Bounds, 2009). Curriculum is critical in providing high quality educational programs and services; however, there are gaps between how curriculum is developed and how curriculum is supposed to be developed in theory. This dilemma is further complicated by the fact that there are huge differences between the curriculum published by the educational institutions and the curriculum actually taught by the teachers in their classrooms. Curriculum is considered as a foundation stone for the "well-being and effectiveness of higher education" (Barnett & Coate, 2005, p. 7). Regardless of how curriculum is defined and what are its scope and importance, it is one of the most significant matters in higher education; however, little attention has been given to the evolution of curriculum, its review and transformation in the institutions of higher education (Hyun, A study of US Academic Deans' involvement in college students' academic success., 2009) (Hyun, 2006). This notion is further strengthened by the fact that there is dearth of research works on the subject and the literature that exists is mostly focused on the design of the curriculum (Hicks, 2007).

Classification of separations: The purpose of a separation may be *analytical*, i.e. to help analyze components in the original mixture without any attempt to save the fractions, or may be *preparative*, i.e. to "prepare" fractions or samples of the components that can be saved. The separation can be done on a small scale, effectively a *laboratory* scale for analytical or preparative purposes, or on a large scale, effectively an *industrial* scale for preparative purposes, or on some *intermediate* scale. Therefore, designing an appropriate curriculum is considered (as) a foundation stone for high quality programs and services, regardless of the type of educational programs and institution Separations are carried out based on differences in chemical properties or physical properties such as size, shape, mass, density, or chemical affinity, between the constituents of a mixture. They are often classified according to the particular differences they use to achieve separation. There are a variety of criteria by which separations can be classified. One is based on the quantity of material to be processed. Some methods of separation (e.g., chromatography) work best with a small amount of sample, while others (e.g., distillation) are more suited to large-scale operations. Classification may also be based on the physical or chemical phenomena utilized to effect the separation. These phenomena can be divided into two broad categories: equilibrium and rate (kinetic) processes. Table 1 lists some separation methods based on equilibria, and Table 2 indicates those methods based on rate phenomena *(Britannica, 2016).* Curriculum is critical in providing high quality educational programs and services; however, there are gaps between how curriculum is developed and how curriculum is supposed to be developed in theory. This dilemma is further complicated by the fact that there are huge differences between the curriculum published by the educational institutions and the curriculum actually taught by the teachers in their classrooms. Curriculum is considered as a foundation stone for the "well-being and effectiveness of higher education" (Barnett & Coate, 2005). Regardless of how curriculum is

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Table 1:Separations based on phase equilibria

Gas-Liquid	Gas-Solid	Liquid-Solid	Liquid-liquid	Supercritical fluid-solid	Supercritical Fluid-liquid
Distillation	Adsorption	Precipitation	Extraction	Supercritical-Fluid Chromatography	Supercritical-Fluid Extraction
Gas-Liquid Chromatography	Sublimation	Zone melting	Partition Chromatography		
Foam Fractionation		Crystallization			
		Ion Exchange			
		Adsorption			
		Exclusion			
		Clathration			

Table 2: Separations based on rate phenomena

Barrier Separations	Field Separations
Membrane Filtration	Electrophoresis
Dialysis	Ultracentrifugation
Ultrafiltration	Electrolysis
Electro dialysis	Field-flow fractionation
Reverse osmosis	

Research Method

The main aim of the current study is to propose a curriculum (objectives and contents) about "chemical separation methods" course for master students in analytical chemistry. This study is applied based on aim, and descriptive according to the method of data collection. The population in this study consisted of course topics of chemical separation methods in all universities around the world. Samples were 38 University who has selected accessible method. Most universities were in United States of America, United Kingdom and India. To collect data, a researcher-made

table were designed which contained syllabus (chapter name or objects and contents). Then the Iran's syllabuses of this course for undergraduate and graduate were studied.

Results

Table 3 shows the course syllabus for master degree in different universities. For example: in University of California, number 19, GPC, SEC, electrophoresis, liquid-liquid extraction, crystallization, dialysis and reverse osmosis are taught.

Table 3 : Syllabus for Chemical Separation Methods Course in Different Countries for Master Degree

Syllabus \ University **	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
GC	✓	✓	✓			✓	✓			✓	✓	✓	✓	✓	✓					✓
HPLC	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
TLC							✓		✓	✓	✓	✓			✓					
GPC – SEC				✓		✓	✓					✓		✓	✓				✓	✓
(GC – MS) (LC – MS)		✓		✓	✓			✓	✓								✓			
Electrophoresis		✓		✓				✓											✓	
CE				✓		✓		✓	✓			✓								✓
Liquid – Liquid extraction						✓	✓		✓			✓			✓	✓			✓	
Solid phase extraction									✓						✓					
Distillation															✓					
Crystallization																			✓	
Dialysis – Reverse Osmoses				✓															✓	

Continued Table 3 Syllabus for Chemical Separation Methods Course in Different Countries for Master Degree

Syllabus \ University **	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
GC	✓		✓			✓	✓			✓	✓			✓	✓	✓		✓
HPLC	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓
TLC																		
GPC – SEC					✓		✓				✓							
(LC – MS) (GC – MS)	✓	✓			✓	✓			✓		✓	✓			✓			
Electrophoresis			✓		✓				✓									
CE					✓				✓					✓	✓			
Liquid – Liquid extraction			✓		✓													
Solid phase extraction																		
Distillation	✓		✓															
Crystallization																		
Dialysis Reverse osmosis					✓													

Universities (Name & Countries)

1- Shivaji University - India
2- Savitribai Phule Pune University – India
3- Andhra University – India
4- University Of Mumbai – India
5- SNDT Women's University – India
6- North Maharashtra University – India
7- Sant Gadge Baba Amravati University – India
8- Veer Narmad South Gujarat University – India
9- NIT Warangal Stadium – India
10- University of Calicut– India
11- Nims University – India
12- Postgraduate Institute of Science – Sri Lanka
13- American University of Sharjah – United Arab Emirates
14- Jordan University of Science and Technology (JUST) – Jordan
15- DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY – India
16- Southwestern Oklahoma State University – United States - Oklahoma
17- Centro de Tecnologia da UFSM – United States - Brazil
18- Mercyhurst University - United States - Pennsylvania
19- University of California Irvine - United States - California
20- University of Alberta - United States - Canada
21- University of South Carolina - United States - Columbia
22- The University of New Orleans - United States - New Orleans
23- Seton Hall University - United States – New Jersey
24- The American University in Cairo – Egypt - Cairo
25- University of Nairobi – Kenya
26- University of Ibadan – Nigeria
27- University of South Africa (UNISA) - Muckleneuk Campus – South Africa
28- University of Southampton High field Campus – United Kingdom
29- Kingston University - United Kingdom
30- Bangor University – United Kingdom
31- University of Kent - United Kingdom
32- University of Aberdeen – United Kingdom
33- Nottingham Trent University – United Kingdom
34- Kungliga Tekniska Högskolan - Sweden
35- Copenhagen University - Denmark
36- Illinois Institute of Technology – United States - Chicago
37- Umea University – Sweden
38- De La Salle University-Manila – Philippines

Undergraduate Syllabus in Iran, 2 Unit

Ministry of Science, Research and Technology revised the chemistry undergraduate curriculum in 2015. In this curriculum, a course named "separation techniques in analytical chemistry" was incorporated for the first time. This 2 units course is theoretical and its prerequisite is analytical chemistry 3 (principles of instrumental analytical chemistry). Main

topics of this course are extraction techniques, chromatographic methods and their applications. The course details are shown below.

1- Extraction Methods: Liquid – Liquid extraction, the use of absorbent in extraction – The Phenomenon of Osmosis- Methods of Dialysis and Electro dialysis- Electrophoresis.

2-Chromatographic Methods: introduction to chromatograph gas chromatography (GC) – High performance Liquid chromatography (HPLC) – Capillary Electrophoresis (CE) – Supercritical Fluid Chromatography and Extraction.

3-Applications: The Application of Separation Methods in Petroleum, Pharmacy, Pharmaceutical Plants and Foods.

Master Syllabus in Iran, 3 Unit

In 1994, Ministry of Science, Research and Technology revised master program of analytical chemistry and proposed a course named "physical and chemical separation methods". Advanced Analytical Chemistry course is a prerequisite for this course. Details of the course are shown below.

1- Liquid – Liquid Extraction and Separation with Clathrate Formation
2- Fractional Distillation and Sublimation
3- Zone Melting and Thermal Diffusion
4-Organic and Inorganic Ion Exchanger; Cellulose and Activated Carbon for the Separation and Its Application in the Wood Industry, Power Plants and Nuclear Reactors.
5- Flotation and Foam Filtration
6- Membrane Methods
7- Dialysis and Electrodialysis
8- Other Biological Separation Methods.

Finally, by comparing the syllabuses in 38 universities, a universal syllabus course is proposed. This course 3 units and theoretical and the "Advanced Analytical Chemistry" course is its prerequisite. The details of proposed curriculum are in below.

Proposed universal syllabus for chemical separation methods in master degree

Gas chromatography:

An Overview of Gas Chromatography Instrumentation
Carrier Gas and Flow Regulation
Variety of Methods Sample Injection and Injection Chamber
Thermostatically Controlled Oven
Packed and Capillary Columns
Stationary Phases
Gas Chromatographic Detectors (Nitrogen Phosphorus Detector (NPD) – Photo Ionization Detector (PID) – Mass Spectrometer as Detector (GC-MS)
Fast Gas Chromatography
Two-dimensional Gas Chromatography (GC×GC)
Kovats and Mc.Reynolds Retention Index
Optimization of a Gas Chromatography

Filtration Methods

Filtration
Microfiltration
Ultrafiltration and Nano filtration
Reverse Osmosis
Examples of Application Methods for Filtration in Various Industries

Advanced Techniques of Extraction

Liquid – Liquid Extraction
Pairs Ion Extraction
Solvent Micro Extraction (SME)
Cloudy Point Extraction
Solid Phases Extraction (SPE)

Electrophoresis

An Overview of Electrophoresis
Zone Electrophoresis
Low and High Voltage Electrophoresis
Continuous Electrophoresis
Gel Electrophoresis

Capillary Electrophoresis and Electrochromatography

Capillary Electrophoresis
Applications of capillary Electrophoresis
Capillary Electrochromatography

Size Exclusion Chromatography and gel permeation chromatography

Principle of SEC
Stationary and Mobile Phases
Calibration Curves
Instrumentation
Applications of SEC

Supercritical Fluids Chromatography

Supercritical Fluids: a Reminder
Supercritical Fluids as a Mobile phases
Instrumentation in SFC

Comparison of SFC with HPLC and GC

High-performance liquid chromatography

The beginnings and introduction of HPLC
General concept of an HPLC system
Pumps and gradient elution
Injectors
Columns
Stationary phases
Chiral chromatography
Mobile phases
Ion Paired chromatography
Hydrophobic interaction chromatography
Detectors
Evolution and applications of HPLC
Bonded Phase Chromatography
Ion Exchange Chromatography
Affinity Chromatography

Thin layer, planer and column chromatography

Principle of TLC
Separation and Retention Parameters
Solvents or Mobile Phase Selection and Stationary Phases
Qualitative TLC
Column Chromatography and Its Application for Preparative Separation

Hyphenated techniques

(GC-MS)(LC-MS)
(GC-MS-MS)
(LC-MS-MS)
(GC-HPLC)
(LC-HPLC)

Distillation

Simple Distillation
Fractional Distillation
Vacuum Distillation
Extractive Distillation

Crystallization

Principle of Crystallization
Solvent Selection
Development and Run of a Crystallization Experiment

Website Addresses for Studied Universities

1- http://www.pgis.lk/assets/syllabi/anc.pdf
2- http://www.unipune.ac.in/dept/science/chemistry/chemistry_webfiles/pdf/mscchemistry.pdf
3- http://www.andhrauniversity.edu.in/syllabus/pgOCFDW.pdf
4- http://www.jaihindcollege.com/aided/science/senior-college/pdfs/4-21-M-Sc-Part-I-sem-1-and-2-chemistry-29-10-15.pdf http://sndt.digitaluniversity.ac/downloads/syllabus_M.Sc.pdf
5- http://nmu.ac.in/Portals/10/socs%20syllabi/M.%20Sc.%20II%20Analytical%20Chemistry%20Syllabus%20June%202011.pdf
6- http://www.sgbau.ac.in/m.sc.-chemistry-08.pdf
7- http://www.vnsgu.ac.in/AutoIndex-2.2.4/Syllabus%20(2011-2012)/Faculty%20of%20%20Science%20as%20per%20CBCS/M.Sc.%20CBCS/M.Sc.%20Chemistry%20CBCS%20%20201112/MSc%20Chemistry%20Regular%20Semesterwise%202011/Analytical/Analytical%20Chemistry.pdf
8- http://www.nitw.ac.in/nitw/Scheme&Syllabus-2012/MSC_Chemistry.pdf
9- http://www.universityofcalicut.info/syl/MScChemistrySyllabusCSSPG2010Affiliatedcolleges.pdf
10- http://dcminstitute.com/Traditional%20Programmes/MSC-BCHM_SYLLABUS.pdf
11- http://www.pgis.lk/assets/syllabi/anc.pdf
12- http://www.aus.ac.in/syllabus/2015-16/chemistry/MSc-Syll-2015-16.pdf
13- http://www.just.edu.jo/FacultiesandDepartments/FacultyofGraduateStudies/Documents/Master%20Degree%20in%20Chemistry%20(English%20Version).pdf
14- http://www.bamu.net/petsyllabus/syllabus/chemistry/M.%20Sc%20I%20&%20II%20semester.pdf
15- http://www.swosu.edu/resources/catalog/course-descriptions/graduate.pdf
16- http://laprw2015.com/docu_web/IonaraPizzuttiINGLES.pdf
17- http://www.mercyhurst.edu/sites/default/files/uploads/08/22/2014%20-%2011%3A38/Mercyhurst%20University%202014%20Catalog%20web.pdf
18- http://catalogue.uci.edu/pdf/2014-15.pdf
19- https://uofa.ualberta.ca/chemistry/graduate-program/courses
20- http://www.chem.sc.edu/analytical/chem723/syl.html
21- http://www.uno.edu/registrar/registrar-docs/1516catalog.pdf
22- https://www.shu.edu/academics/upload/Graduate-Catalogue-2014-2015-with-bookmarks.pdf
23- http://catalog.aucegypt.edu/mime/media/view/15/938.pdf
24- http://sps.uonbi.ac.ke/uon-degrees-details/2320/courses/#.course-anchor-2320-2327
25- http://www.saci.co.za/Analitika/pdf/Harmonizing%20Analytical%20Chemistry%20Curricula-Workshop%20report.pdf
26- http://www.unisa.ac.za/contents/studyinfo/docs/download/brochures_2009/chem_e.pdf
27- http://www.southampton.ac.uk/chemistry/postgraduate/taught_courses/instrumental_analytical_chemistry.page
28- http://www.kingston.ac.uk/postgraduate-course/analytical-chemistry-msc
29- https://www.bangor.ac.uk/courses/postgraduate/analytical-chemistry-msc-pgdip
30- https://www.kent.ac.uk/courses/postgraduate/18/chemistry#!study-support
31- http://www.abdn.ac.uk/study/courses/postgraduate/taught/analytical_chemistry/
32- http://www.ntu.ac.uk/apps/pss/course_finder/60823-1/9/mres_analytical_chemistry.aspx
33- http://www.kth.se/student/kurser/kurs/KD2030-20072.pdf
34- http://dra.ku.dk/courses/phdcourses2015/2015__Mass_Spectrometry_Coupled_to_Separation_Techniques_in_Bioanalytical_Chemistry.pdf
35- https://science.iit.edu/chemistry/programs/course-descriptions#CHEM508
36- http://www.umu.se/english/education/courses-and-programmes/course?current
37- http://www.dlsu.edu.ph/academics/graduate-studies/_pdf/cos/chemistry/MSChem.pdf

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