SULTAN QABOOS UNIVERSITY

COURSE OUTLINE

PROGRAM: Chemistry

1. Course Code	CHEM6613	
2. Course Title	Advanced Inorganic Chemistry II	
3. Credits	3	
4. Pre-requisite Course(s)	CHEM4411	
5. Co-requisite Course(s)	none	
6. Equivalent Course(s)	none	
7. Incompatible Course(s)	none	
8. Course Category	☐ University Requirement	☐ University Elective
	☐ College Requirement	☐ College Elective
	☐ Department Requirement	☒ Department Elective
	☐ Specialization Requirement	☐ Specialization Elective
	☐ Other (specify):	
9. Course Owner	College: Science	Department: Chemistry
10. Course Type	☒ Lecture	☐ Lecture/Lab
	☐ Lecture/Seminar	☐ Lecture/Studio
	☐ Lecture/Tutorial	☐ Lecture/Lab/Tutorial or Seminar
	☐ Tutorial	☐ Laboratory (Practical)
	☐ Field or Work Placement	☐ Studio
	☐ Seminar	☐ Internship
	☐ Workshop	☐ Project
11. Language of Instruction	English	

12. Course Description

This course commences with the fundamentals of d-block metal-carbon interactions in organometallic and cluster chemistry; subsequently, it progresses towards advanced organometallic chemistry concepts and principles pertaining to chemical structure and bonding, reactivity and practical applications in organic synthesis and industrial catalysis. The major topics include synthetic routes to different classes of d-block organometallic compounds and metal carbonyl clusters, chemical bonding involving M–L exchanges of electrons through sigma and pi interactions, reactivity and stability of organometallic complexes, types of reactions occurring at the metal centre or in the attached ligands, homogeneous and heterogeneous catalyses in which organometallic compounds are used as catalysts or are generated as intermediates in the catalytic cycles, and physical techniques of characterisation in organometallic chemistry. Towards the end of the course the students will conduct a literature review of selected research topics in organometallic chemistry and metal cluster chemistry for class discussions and as an assignment in the form of a seminar or written presentation.

13. Teaching/Learning Strategies

Lectures, class discussions, demonstrations, models, literature survey and Moodle

14. Assessment Components and Weight [%]

☒ Quizzes ()	☐ Practical	☐ Other (specify):
☒ Homework assignments ()	☐ Project	
☒ In-term examination(s) (50)	☒ Final examination (50)	

15. Grading Method

☒ A-F Scale ☐ Pass/Not passed

16. Textbook(s) and Supplemental Material

1. The Organometallic Chemistry of the Transition Metals, Fourth Edition, R.H. Crabtree, John Wiley & Sons Inc., ISBN-13: 978-0471662563.

2. Organometallics - A Concise Introduction, Second, Revised Edition, Ch. Elschenbroich, A. Salzer, VCH, Weinheim, ISBN-3-527-28165-7

3. Metallocene: Synthesis, Reactivity and Applications, Volume 1 and 2, A Togni and R.L. Halterman, Wiley-VCH Verlag GmbH, ISBN-13 978-3527306459

17. Matching Course Objectives with Program Outcomes and SQU Graduate Attributes

SQU Graduate Attributes

A. SQU graduates should be able to:	**B. SQU graduates possess**	**C. SQU graduates should**
1. apply the knowledge and skills relevant to the specialization 2. communicate effectively and use information and communication technologies 3. critically analyze complex information and present it in simple clear manner	1. interpersonal communication skills and alignment with culture of international labour market to assist them in practical life and in living successfully 2. skills and motivation for independent learning and engagement in lifelong learning and research 3. work ethics and positive values, and intellectual independence and autonomy 4. teamwork skills and display potential leadership qualities	relish good citizenship qualities, be conscious of their national identity and be socially responsible, engage in community affairs and be mindful of contemporary issues.

#	Intended Student Learning Outcome /Course Learning Objective	Relevant Program Outcome(s)	Applicable Attribute(s)
1.	Define organometallic and metal cluster complexes, and give pertinent examples with a wide range of ligands	PLO 1-3	A1
2.	Explain briefly and exemplify with Zeise's complex anion how a d-block metal interacts with an organic ligand using appropriate orbitals	PLO 1-3	A1
3.	Use MO theory to explain the 18- and 16-electron rules in d-block organometallic chemistry and cluster chemistry	PLO 1-3	A1
4.	Apply the donor-pair and neutral-ligand methods to count the total valence electrons of a d-block organometallic or cluster compound	PLO 1-3	A1
5.	Predict products of chemical reactions and stabilities of compounds in organometallic chemistry and cluster chemistry based on the electron-counting rules	PLO 1-3	A1
6.	Apply IUPAC recommendations to name simple organometallic and cluster compounds and to write their chemical formulae	PLO 1-3	A1
7.	Describe, show and exemplify how alkyl, aryl, alkenyl and alkynyl ligands use sigma interaction to attach to central d-block metals in their complexes	PLO 1-3	A1
8.	Sketch the bonding and antibonding pi-molecular orbitals of alkene, alkyne, allyl, diene, polyene, cyclopentadienyl (Cp) and benzene ligands, and show their relative energies using simple energy-level diagrams	PLO 1-3	A1
9.	Explain and illustrate with diagrams the sigma- or pi-donor/pi-acceptor interactions between d-block metals and alkenes, alkynes, allyl, dienes and polyenes in organometallic complexes	PLO 1-3	A1
10.	Discuss the aromaticity of cyclopentadienyl and benzene, and describe and explain their chemical reactions to form stable organometallic complexes	PLO 1-3	A1

11.	Explain the relative stabilities of the d-block metallocenes; discuss the chemical bonding and reactivity of ferrocene; compare and contrast between the chemical reactions of ferrocene and those of the benzene molecule	PLO 1-3	A3
12.	Distinguish between the Fischer-type and Schrock-type carbene complexes; explain the differences between these complexes in terms of the d-block metal-carbene bonding, nature of central d-block metal and types of reactions	PLO 1-3	A1 & A3
13.	Draw the energy-level diagram for the molecular orbitals of CO and identify the frontier orbitals; illustrate with diagrams how the CO ligand acts as a sigma-donor/pi-acceptor towards a d-block metal	PLO 1-3	A1
14.	Describe the different binding modes of CO and explain how they can be identified by vibrational (IR) spectroscopy; explain the influence of other ligands in the same complex as sigma-, pi-donors or pi-acceptors on the carbonyl stretching frequencies	PLO 1-3	A1
15.	Describe the synthesis of d-block metal carbonylates (anionic carbonyl complexes) and show their tendency to comply with the 18-electron rule; explain their characteristic IR absorptions; explain and exemplify practical synthetic applications of carbonylates as nucleophiles	PLO 1-3	A1
16.	Describe synthetic routes to transition metal clusters; correlate the cluster valence electron count with the cluster geometry; explain and exemplify the isolobal analogy; discuss practical synthetic applications of the isolobal analogy	PLO 1-3	A1
17.	Apply physical techniques such as crystallography and spectroscopy to characterise organometallic and cluster compounds and to identify intermediates in catalytic cycles	PLO 1-3,8,9	A1
18.	Explain and exemplify organometallic reactions including the following: ligand substitutions, oxidative addition, reductive elimination, insertions, deinsertions, nucleophilic and electrophilic reactions	PLO 1-3	A1 & A3
19.	Discuss homogeneous and heterogeneous catalyses; describe and explain practical applications of catalysis in organic synthesis and industrial processes; predict intermediates in catalytic cycles of selected chemical processes	PLO 1-3,8,9,11	A1 & A3
20.	Demonstrate mastery of organometallic principles by reading, understanding, discussing and critiquing journal articles in organometallic and cluster chemistry; make an oral OR written presentation	PLO 1-6,8,9,11	A1–3; B2

16. Student Responsibilities

It is the student's responsibility to know and comply with all University Academic Regulations relevant to participation in this course. These regulations specifically include attendance requirement and students` academic code of conduct.

For attendance, it is the student's responsibility to be punctual and to attend all classes.

Students are expected to perform their work with honesty and avoid any academic misconduct, which is defined as the use of any dishonest or deceitful means to gain some academic advantage or benefit. This can take many forms, including but not limited to, the following: copying, plagiarism, collusion and forging documents. For full details, please refer to the Undergraduate Academic Regulations and to the Student Academic Misconduct Policy.

Additionally, this course requires that you:

Take responsibility for your own education and be aware of all notices made by the instructor about course activities

COURSE INFORMATION			
Course Code	CHEM6613	**Course Title**	Advanced Inorganic Chemistry II
Semester/ Year	SP23	**Section(s)**	10
Day, Time, and Place			

Course Coordinator			
Office Location		**Office Hours**	
Office Tel. Ext.		**Email**	

Tentative Schedule			
Week	**Lecture #**	**Topic/Material to be covered**	**Assessment**
1	1-2	Overview of d-block organometallic and metal cluster chemistry: definitions, distinguishing features from other areas of inorganic chemistry, classification, applications and historical development of organometallic and metal cluster compounds; examples of organometallic compounds and metal cluster complexes with a diverse range of ligands	
2	1-2	The 18- and 16-valence electron rules: explanations using MO theory, correlations with the appropriate geometries at the d-block metal centres; applications in synthesis and catalytic processes; a list of organic and non-organic ligands (ions, molecules and molecular fragments) with the number of electrons they donate to the metal centre; nomenclature of simple complexes	
3	1-2	Valence-electron counting schemes in d-block organometallic and cluster compounds: the donor-pair method vs. the neutral-ligand method; prediction of stability of complexes; hapticities of some organic ligands via sigma- & pi-bonding; examples of syntheses and typical reactions of organometallic and cluster compounds consistent with the valence-electron count	
4	1-2	Chemical bonding in some organic ligands: sigma-donor ligands (alkyl, aryl, alkenyl, alkenyl); sigma- or pi-donor/pi-acceptor ligands (alkenes, alkynes, allyl, dienes, polyenes, cyclopentadienyl (Cp), benzene and other arenes); pi-molecular orbitals and simple energy-level diagrams; sigma-, pi-donation/pi-backbonding synergism; syntheses and reactions of corresponding complexes	Quiz 1
5	1-2	Fischer-type versus Schrock-type carbene complexes: differences in sigma-pi interactions, nature of d-block metal centres and reactivities as nucleophilic or electrophilic; chemical bonding of non-organic ligands (hydride, dihydrogen and phosphines) in organometallic and metal cluster compounds; effects of phosphine substituents & Tolman's cone angles on reactivity and stability	
6	1-2	Aromaticity of the cyclopentadienyl anion and benzene (in conformity with Huckel 4n + 2 rule): pi-bonding and antibonding orbitals of Cp and benzene and their relative energies; syntheses, relative stabilities and importance of d-block metallocenes; reactivity and synthetic applications of ferrocene	Test 1
7	1-2	The carbonyl ligand and its d-block metal complexes: MO energy level diagram, frontier orbitals, sigma-donor/pi-acceptor interactions with d-block metals, correlation of binding modes with carbonyl stretching frequencies, influence of sigma-donor/pi-donor/pi-acceptor co-ligands in metal carbonyl complexes on the carbonyl bond strength; syntheses, vibrational spectra and synthetic applications of carbonylate (anionic carbonyl) complexes	
8	1-2	Transition metal clusters: definition and examples of metal clusters, synthetic routes to d-block metal carbonyl clusters, structures and bonding; correlation of cluster valence electrons (CVE) with cluster geometry, determination of M-M interactions from CVE and nuclearity, isolobal analogy between metal carbonyl and main-group fragments, synthetic applications of the isolobal analogy	
9	1-2	Practical methods of synthesis (including Schlenk-line techniques), isolation and purification of complexes; physical techniques of characterization of	

		organometallic and metal cluster complexes including single-crystal X-ray crystallography and spectroscopic techniques (FT-IR, 1-H NMR, 13-C NMR and 31-P NMR)	
10	1-2	Selected types of chemical reactions of organometallic and metal cluster complexes occurring at the metal centre: ligand substitutions (associative and dissociative), oxidative addition and reductive elimination; selected types of chemical reactions of organometallic and cluster complexes involving modification of attached ligands: insertion and deinsertion, nucleophilic attack on attached ligands, electrophilic attack on attached ligands	
11	1-2	Catalysis using organometallic compounds: definition of a catalyst; types and properties of catalysts, examples of organometallic catalysts; concepts and principles of catalysis, applications in industrial processes; homogeneous catalytic applications in selected chemical processes: hydrogenation of alkenes, polymerization and oligomerization of alkenes, oxidation of alkenes, hydroformylation (hydrocarbonylation), Monsanto acetic acid synthesis, Fischer-Tropsch chemical reactions	Test 2
12	1-2	Chiral ferrocenyl compounds in asymmetric catalysis, Organometallic polymers in materials application; heterogeneous catalysis: advantages and disadvantages over homogeneous catalysis, applications of heterogeneous calalysis	
13	1-2	Selected journal articles in d-block organometallic and cluster chemistry for class activity: students will be required to demosntrate mastery of the concepts and principles in organometallic chemistry	
14	1-2	Literature review on selected research topics in d-block organometallic and cluster chemistry: students will be introduced to original research in this field of inorganic chemistry	
15	1-2	Extended research assignment in d-block organometallic chemistry or cluster chemistry: written OR oral presentation	Assignment
16			Final exam
17			

APPENDIX A: INSTRUCTORS OF MULTIPLE SECTIONS					
Section	**Instructor**	**Day, Time, and Place**	**Office Location and Extension**	**Email**	**Office Hours**

APPENDIX B: ADDITIONAL INFORMATION