Inorganic and Analytical Chemistry

S/N: 10421040
Classification: Specialized Basic Course
Applicable to: Chemical Engineering and Technics Food Science and Engineering Biological Engineering Pharmaceutical Engineering Materials Science and Engineering
Total Hours for Theory: 68 Credit Points: 68
Requirements on Foundation Course: Advanced Mathematics
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A. Characteristics and Status

As the first compulsory basic course of chemistry for majors of chemical engineering and technics, food science and engineering, biological engineering, pharmaceutical engineering, materials science and engineering and so on in the institutions of higher learning, inorganic and analytical chemistry is not only an important component of cultivating integral knowledge structure and capability structure of engineering and technical talents of the said majors, but also a foundation for the subsequent specialized courses.

B. Teaching Targets

The course aims to enable students to master basic theories of substance structure, basic principles and application of chemical reaction, basic knowledge of element chemistry, knowledge of and relations among structure, equilibrium, characteristic and application, to resolve general problems of inorganic and analytical chemistry with its theories, to select test approaches of analytical chemistry, estimate and express test results correctly, and to lay foundation for resolving real problems existing in production and scientific researches, through classroom lecturing and close combination with test course of inorganic and analytical chemistry. Furthermore, through the establishment of strict concept of “quantity”, this course also aims to cultivate students’ good learning habits, rigorous scholarship, practical and realistic attitude toward science and ability of analyzing and resolving problems, so that students will acquire scientific qualities necessary to scientific and technical personnel gradually.

C. Teaching Contents, Basic Requirements and Time Allocation

Introduction

To find out major contents of the course of inorganic and analytical chemistry and their mutual relations, master learning approaches of this course, understand requirements on learning this course, learn about targets and characteristics of inorganic and analytical chemistry, and find out the classification and evolvement of analytical approaches.

Major Contents

0.1 Objects and contents of chemical research

0.2 Major contents of the course of inorganic and analytical chemistry

0.3 Learning approaches for the course of inorganic and analytical chemistry

0.4 Requirements on learning the course of inorganic and analytical chemistry

Key Points:

1. Learning approaches for the course of inorganic and analytical chemistry
2. Requirements on learning the course of inorganic and analytical chemistry

Nodus:

Knowledge of and relations among structure, equilibrium, characteristic and application in teaching contents of inorganic and analytical chemistry

Chapter 1 Chemometrics and Error and Data Processing

To find out basic steps of general analytical course (sampling, pre-processing, measurement and result calculation), to establish the concept of "quantity" clearly, to master basic knowledge of error, causes of error and ways of reduction and avoiding, basic approaches of data processing, application of significant data, rejection of doubtful data and correct formulation of analytical results, to learn about concepts of confidence level and confidence interval, to master basic concepts of titrimetric analysis, application of titrimetric analysis and calculation methods of titrimetric analysis, and to learn about the evolvement of titrimetric analysis.

Major Contents

1.1 Measurement and stoichiometric calculation in chemical reaction

1.1.1 Measurement in chemistry and International System of Units

1.1.2 Introduction to titrimetric analysis

1.1.3 Measuring relations and stoichiometric calculation in chemical reaction

1.2 Error and significant figure

1.2.1 Classification of error

1.2.2 Reduction and avoiding of error

1.2.3 Formulation of Error

1.3 Significant figure

1.4 Processing of test data

1.4.1 Formulation of testing results

1.4.2 Confidence level and confidence interval

Key Points:

1. Basic steps of general analytical course (sampling, pre-processing, measurement and result calculation)
2. Basic knowledge of error
3. Causes of error and ways of reduction and avoiding, and basic methods of data processing
4. Basic concepts and calculation methods of titrimetric analysis
5. Application of significant data, rejection of doubtful data and correct formulation of analytical results

Nodus:

1. Rejection of doubtful data and correct formulation of analytical results
2. Confidence level and confidence interval

Chapter 2 Basic Principles of Chemical Reaction

To learn about concepts of rate equation of chemical reaction (law of mass action) and reaction orders, to master factors of influencing rate of chemical reaction, and to know ways of formulating the influence of concentration, partial pressure, temperature and activator toward rate of reaction by using concepts of activation energy and molecule.

To master rules of chemical equilibrium and equilibrium movement, to be capable of calculating the components of equilibrium with equilibrium constant (K^{θ}), and to understand the factors needs calculating synthetically for rate of reaction and chemical equilibrium in practical use.

Major Contents:

2.1 Rate of chemical reaction and its affecting factors

2.1.1 Rate of chemical reaction

2.1.2 Affecting factors of rate of chemical reaction

2.2 Processing limit of chemical reaction

2.2.1 Chemical equilibrium and equilibrium constant

2.2.2 Movement of chemical equilibrium

Key Points:

1. Rules of chemical equilibrium and equilibrium movement and to be capable of calculating the components of equilibrium with equilibrium constant (K^{θ})

2. Concepts of rate equation of chemical reaction (law of mass action) and reaction orders

3. Affecting factors of rate of chemical reaction

Nodus:

1. Formulating the influence of concentration, partial pressure, temperature and activator toward rate of reaction by using concepts of activation energy and molecule

2. Processing and calculation concerned with chemical equilibrium

Chapter 3 Acid-base Equilibrium & Acid-base Titration

In this chapter we can learn the basic notion of the theory of Brønsted-Lowry, the concept of the activity, status of the strong electrolyte solution, understand the contents and correlative calculations of dissociation degree of weak electrolyte, dilution law, acidity of solution and pH, dissociation equilibrium (include grade dissociation equilibrium) , common ion effect, buffer solution and so on, master the principle of method of titration, titration curve, end point judge , end point error and so on ,understand the law of pH changing in various processes of acid-base titration and the way of choosing the right indicator.

Major Contents:

3.1 Theory of Brønsted-Lowry and acid-base equilibrium

3.1.1 Acid-base dissociation equilibrium and constant of dissociation equilibrium

3.1.2 Relation between Ka & Kb of conjugated pair of acid-base

3.2 Moving of acid-base dissociation equilibrium

3.2.1 Dilution law

3.2.2 Common ion effect,

3.2.3 Activity, ionic strength and salt effect

3.3 Distributing of constituents in acid-base dissociation equilibrium and the calculation of the concentration

3.3.1 Distribution factor and distribution curve
3.3.2 Calculation about equilibrium concentrations of constituents
3.4 Calculation of solution acidity
3.4.1 Confirmation of proton balance equation
3.4.2 Calculation of acidity of weak mono-acid (alkali)
3.4.3 Calculation of acidity of ampholyteric compound solution
3.5 Control and detection of the solution acidity
3.5.1 Acid-base buffer solution
3.5.2 Acid-base indicator
3.6 Acid-base titration
3.6.1 Strong alkali (acid) titrate strong alkali(acid)
3.6.2 Strong alkali (acid) titrate weak mono-acid (alkali)
3.6.3 Titration of polyatomic acid and mixed acid
3.6.4 Application of acid-base titration

Key Points:

1. The contents and correlative calculations of dissociation degree of weak electrolyte, dilution law, acidity of solution and pH, dissociation equilibrium, common ion effect, buffer solution and so on.
2. Basic concepts of acid-base titration (titration, end point, stoichiometric point, indicator, standard solution, standard substance)
3. Principle of acid-base titration analysis, titrate curve, end point judgement, end point error
4. Application of acid-base titration and calculation of titration result.

Nodus:

1. The law of pH changing in various processes of acid-base titration and the way of choosing the right indicator.
2. Distribution factor and distribution curve, confirmation of proton balance equation
3. Calculation of acidity of ampholyteric compound solution, and titration of the mixed acid and polyatomic acid

Chapter 4 Precipitation-dissolution Equilibrium & Precipitation Testing Method

In this chapter we can learn contents and relative calculations about precipitation-dissolution equilibrium , solubility product principle and so on, learn how to judge whether precipitation or dissolution will come out with the solubility product principle, master calculation of fractional precipitation, learn the principle of precipitation titration analysis, end point judge, understand the application of precipitation titration analysis and calculation of titration result, learn the feature of gravimetric method and its principle and process.

Major Contents:

4.1 Formation of precipitation and dissolution equilibrium
4.1.1 Solubility product principle and solubility
4.1.2 Dominant factor for solubility
4.2 Solution of precipitation ,fractional precipitation and inversion of precipitation
4.2.1 Fractional precipitation
4.2.2 Application of fractional precipitation
4.2.3 Inversion of precipitation

4.3 Formation of precipitation
4.3.1 Kinds of precipitation
4.3.2 Formation of precipitation
4.3.3 Factor for purity of precipitation
4.3.4 Measure for good pure precipitation
4.4 Precipitation testing method
4.4.1 Gravimetric method
4.4.2 Precipitation titration analysis
Key Points:
1. Precipitation-dissolution equilibrium, solubility product principle
2. Judge whether precipitation or dissolution will come out with the solubility product principle, feature of gravimetric method and its principle and process.
3. Application of precipitation titration analysis and calculation of titration result
Nodus:
1. Fractional precipitation and relative calculation
2. Principle of precipitation titration analysis and end point judge
3. Application of precipitation titration analysis and calculation of titration result

Chapter 5 Redox Equilibrium and Redox Titration

In this chapter we can learn contents and relative calculations about redox equilibrium, electrode potential and so on, understand the principle of redox titration, learn the way of choosing the right condition for redox titration, master application of redox titration analysis and calculation of titration result.

Major Contents :
5.1 Redox reaction and electrode potential
5.1.1 Oxidation number
5.1.2 Balancing of equation of redox reaction
5.2.1 Primary battery
5.2.2 Electrode potential
5.2.3 Standard electrode potential
5.2.4 Factor for electrode potential
5.2.5 Conditional potential
5.3 Application of electrode potential
5.3.1 Calculation of electromotive force of primary battery
5.3.2 Judge the direction of redox reaction
5.3.3 Judge the limitation of redox reaction
5.3.4 Calculation of relative equilibrium constant
5.3.5 Chart of standard electrode potential of elements
5.4 Reaction rate of redox reaction
5.5 Redox titration
5.5.1 Redox titrate curve
5.5.2 Detection of the end of redox titration
5.5.3 Redox titration analysis
5.5.4 Calculation of redox titration result
Key Points:

1. Contents and relative calculations about redox equilibrium, electrode potential etc.
2. Basic concepts of redox titration analysis (titration, end point, stoichiometric point, indicator, standard solution, standard substance).
3. Principle of redox titration analysis, titrate curve, end point judge, end point error and feasibility of titration
4. Application of redox titration analysis and calculation of titration result.

Nodus:

1. Ways of choosing the right condition for redox titration
2. Principles of redox titration analysis ,titrate curve, end point judge, end point error and feasibility of titration
3. Applications of redox titration analysis and calculation of titration result.

Chapter 6 Atomic Structure and Periodic Properties of the Elements

In this chapter, we need to know about some concepts of atomic structure, such as the movement of extranuclear electron, atomic energy level, probability density, atomic orbital, and wave function. Also understand how to descript the movement of extranuclear electron with the four quantum numbers, as well as the configurations and directions of s, p, and d orbital. Moreover, we should master some general rules of the configuration of extra-nuclear electron, characteristics of valence electron of main group and transition elements, and learn to estimate the properties of the elements according to its electronic shell structures. In this chapter, we also need to know the periodic variation of atomic radius, ionization energy, electron affinity energy as well as electronegativity, and to understand the formation, characteristic (directivity and saturation) , and types of bonding (σ bond and π bond) in the view of valence bond theory. Further more, we should master the types of hybrid orbitals (sp, sp^2, sp^3), which are relative with the molecular configurations. To illustrate molecular structures and magnetic properties, we also should understand some concepts of molecular orbitals. Finally, we should known some types of crystals and its structural characteristics, Born-Haber cycle, and that how crystal lattice influences the melting point and hardness of ionic compounds, and that how to effect the properties of matter by the means of ionic polarization, intermolecular forces and hydrogen bond.

Major Contents:

6.1 The Models of Atomic Structure
6.1.1 The Bohr Model of Atomic Hydrogen
6.1.2 The Quantum Mechanics Model
6.2 The Movement of Extranuclear Electron
6.2.1 The Schroodinger Equation
6.2.2 The Wave Functions and the Atomic Orbitals
6.2.3 The Four Quantum Numbers
6.2.4 The Angular Distribution Pattern of Atomic Orbital
6.2.5 Patterns of Electron Cloud
6.3 The Electronic Shell Structures of the Atoms and The Periodic System
6.3.1 The Configuration of Extra-nuclear Electron of polyelectron Atoms
6.3.2 The Electronic Shell Structures of the Atoms and the Periodic System
6.3.3 Periodic Properties of the Elements
6.4 Covalent Compounds

6.4.1 Valence Bond Theory
6.4.2 Hybrid Orbital Theory
6.4.3 Molecular Orbital Theory
6.5 Intermolecular Forces and Hydrogen Bond
6.5.1 The Polarity and Deformability of Molecules
6.5.2 Intermolecular Forces
6.5.3 Hydrogen Bond
6.6 Ionic Compounds
6.6.1 Formation and Characteristics of Ionic Bond
6.6.2 Ionic Solids
6.6.3 Ionic Radius and Crystal Configurations
6.6.4 Lattice Energy of Ionic Solids
6.6.5 Ionic Polarization
6.6.6 Other Solids

Key Points:

1. Description of the movement of extranuclear electron with the four quantum numbers
2. General rules of the configuration of extra-nuclear electron, and characteristics of valence electron of main group and transition elements
3. Configuration and direction of s, p, d orbitals
4. The atomic radius, ionization energy, electron affinity energy, periodic variation of electronegativity
5. To understand the formation, characteristics (directivity and saturation), and types of bonding (σ bond and π bond) in the view of Valence Bond Theory.
6. The types of hybrid orbitals (sp, sp^2, sp^3) and their relationship with molecular configurations
7. The types of crystals and its structural characteristic

Nodus:

1. Modern concepts of the movement of extranuclear electron, atomic energy level, probability density and electron cloud, atomic orbitals and Wave Functions.
2. Description of the movement of extranuclear electron with the four quantum numbers
3. The concepts of molecular orbitals, and illustration of molecular structure and magnetic property
4. The polarity and deformability of molecules.

Chapter 7 Coordination Compound & Complexometry

In this chapter, we can master complex equilibrium, including cascade complex equilibrium, and some calculations about it and can compute equilibrium compositions when ligands exceed. We should be acquainted with titration of EDTA when various equilibriums exist. And master how to select the acidity of titration and methods for increasing sensitivity of titration.

Major Contents:

7.1 Coordination Compounds and Chelate Compounds
7.1.1 The Elements of Coordination Compounds
7.1.2 The Nomenclature of Coordination Compounds
7.1.3 Chelate Compounds
7.2 Valence Bond Theory of Coordination Compounds

7.2.1 Summary of Valence Bond Theory of Coordination Compounds
7.2.2 Coordinate Covalent Bonds and Steric Configuration
7.2.3 Outer Orbital Complexes and Inner Orbital Complexes
7.2.4 Stability and Magnetic Properties of Coordination Compounds
7.3 Complex Equilibrium and its Influencing Factors
7.3.1 Complex Equilibrium and Equilibrium Constant
7.3.2 EDTA and Coordination Compounds of Metallic Ions
7.3.3 Major Factors Effected on Complex Equilibrium
7.4 Complexometry
7.4.1 Complexometry Curve and Titration Conditions
7.4.2 Indicators for Complex Formation Titration
7.4.3 Selective Titration of Mixed Ions
7.4.4 Modes of Complexometry
Key Points:
1. Basic Concepts of Coordination Compounds and Valence Bond Theory
2. Calculation of equilibrium composition when ligands exceed, Selection of acidity, and methods for increasing selectivity
3. Principles of complexometry, complexometry Curve, recognition of end point error and feasibility
4. The application of complexometry and the methods for the calculation of titration result

Nodus:
1. Valence Bond Theory of Coordination Compounds
2. Calculation of equilibrium composition when ligands exceed, selection of acidity, and methods for increasing selectivity.
3. Applications of complexometry and methods for calculation of the result of titration

Chapter 8 The Common Elements of p Block and Relative Compounds

In this Chapter, we can get to know about the typical properties of the main group compounds (Halogens, Oxygen, Silicon, Nitrogen, Arsenic, Stibium, Bismuth, Calcium, Lead), such as acidic-basic properties, oxidizing-reducing properties, and isolation and identification of ions.

Major Contents:
8.1 The Halogens and Halide Compounds
8.1.1 The Halogens and General Properties of Simple Substances
8.1.2 The Main Halogens
8.2 The Elements of Oxygen Group and its Compounds
8.2.1 General Properties of the Oxygen Group
8.2.2 Oxygen, Sulfur and its Compounds
8.3 The Elements of Nitrogen Group and its Compounds
8.3.1 General Properties of the Nitrogen Group
8.3.2 The Main Compounds of Nitrogen Group
8.4 The Elements of Carbon, Boron Groups and its Compounds
8.4.1 The Common Elements of Carbon Group and its Compounds
8.4.2 The Common Elements of Boron Group and its Compounds

Key Points:

1. Master the typical properties of the main group compounds (Halogens, Oxygen, Silicon, Nitrogen, Arsenic, Stibium, Bismuth, Calcium, Lead), such as acidic-basic properties, oxidizing-reducing properties and isolation and identification of ions
2. Learn to evaluate the products of chemical reactions and write out reaction equation correctly.

Nodus:

Typical properties of the main group compounds, such as acidic-basic properties, oxidizing-reducing properties and isolation and identification of ions

Chapter 9 The Common Elements of s, ds and d Blocks and Relative Compounds

In this chapter, we can get to know about the typical properties of the transition elements (Cr Mn Fe Co Ni Cu Ag Zn Cd Hg) and its main compounds (Halogens, Oxygen, Silicon, Nitrogen, Arsenic, Stibium, Bismuth, Calcium, Lead), such as acidic-basic properties, oxidizing-reducing properties and isolation and identification of ions, and learn about system analytic methods of qualitative analysis.

Major Contents:

9.1 The Common Elements of s Block and Main Compounds
9.1.1 General Properties of the Elements of the s Block
9.1.2 The Main Compounds of s Block
9.2 The Common Elements of ds Block and Main Compounds
9.2.1 Cu, Ag and its Main Compounds
9.2.2 Zn, Cd, Hg and its Main Compounds
9.3 The Common Elements of d Block and Main Compounds
9.3.1 General Properties of the Elements of the d Block
9.3.2 The Main Compounds of Gr
9.3.3 The Main Compounds of Mn
9.3.4 The Main Compounds of Fe, Co and Ni
9.4 Isolation and Identification of Common Metallic Ions
9.4.1 Summary of Inorganic Qualitative Analysis
9.4.2 System Analytic Methods for Common Metallic Ions

Key Points:

1. The typical properties of the transition elements (Cr Mn Fe Co Ni Cu Ag Zn Cd Hg) and its main compounds (Halogens, Oxygen, Silicon, Nitrogen, Arsenic, Stibium, Bismuth, Calcium, Lead), such as acidic-basic properties, oxidizing-reducing properties and isolation and identification of ions.
2. System analytic methods of qualitative analysis

Nodus:

Acidic-basic properties, oxidizing-reducing properties, and isolation and identification of ions of the transition elements and its main compounds

Chapter 10 Spectrophotometric Method

In this chapter, we should understand the selective adsorption of lights by substance, master Lambert-Beer Law, know about methods and instruments of spectrophotometry, selection of chromogenic reaction and measurement conditions, and acquaintance with approach for increase sensitivity and accuracy of instrument.

Major Contents:

10.1 Basic Principles of Spectrophotometric Method

10.1.1 Selective Adsorption of Lights by Substance

10.1.2 Lambert-Beer Law

10.1.3 Factors Influencing Deviation from Lambert-Beer Law

10.2 Spectrophotometric Method

10.2.1 Colorimetric and Specrophotometric Methods

10.2 2 Chromogenic Reaction and its Influencing Factors

10.3 Applications of Spectrophotometric Method

Key Points:

1. Basic principles of spectrophotometric method
2. Lambert-Beer Law
3. Applications of spectrophotometric method

Nodus:

1. Structure and principle of instrument
2. Selection of chromogenic reaction conditions
3. Selection of reference solutions

No.	Contents	Period
0	Introduction	1
1	Stoichiometry and error , data processing	3
2	Basic principle of chemical reaction	4
3	Acid-base equilibrium & acid-base titration	8
4	Precipitation-dissolution equilibrium & precipitation testing method	8
5	Redox Equilibrium and Redox Titration	8
6	Substance structure	10
7	Coordination compound & complexometry	8
8	The Elements of P Block and relative compounds	4
9	The Common Elements of S d ds Blocks and relative compounds, Isolation & identification of common mixed-ions solution	8
10	Spectrophotometric Method	6

D. **Arrangement and Examination Methods for Teaching Segment**

1. Classroom Lecturing

(1). Lecturing: Systematical lecturing shall be carried out for the part of basic theory of this course.

Great attentions shall be paid to the systematization of contents and strictness of logic. Teachers shall impart correct concepts, give prominence to key points, write clearly, distinguish arrangement and consecution, inherit the past and usher in the future, and introduce the cases of scientific researches and engineering in practical use.

(2). The aim of exercise class is to improve students' understanding toward basic concepts and enhance practical ability of basic theory. Therefore, the selection of exercises shall be refined and have a strong aim. Great attentions shall be paid to lead and enlighten students' thinking and put forward discussions to cultivate students' ability of analyzing and resolving problems.

(3). Tutorship: We recommend that you arrange for time of answering problems, mainly through internet and after class.

(4). Teaching methods: Specific teaching form shall be determined by teachers, in conformity with teaching contents, teaching objects, teaching conditions and corresponding teaching experiences. In principle, we recommend that you adopt the form of combination between CAI courseware and blackboard class and use the teaching methods of problem teaching and project teaching reasonably.

Teachers shall impart knowledge and educate students, carry out strict requirements on students in all sectors, and train students' learning targets and style of study with combination of learning the course.

b. Exercise Requirements and Quantities

One of key factors for students to learn the course of inorganic and analytical chemistry well is to fulfill exercise independently in time. Teachers shall supervise and urge students to pay great attention to exercises and require students to review and understand lecturing contents well in advance before exercises, so that targets of lecturing will be consolidated.

(1). Requirements on students: To hand on exercise in time. Suitable ways of criticism shall be implemented on those who hand on exercises later, do not hand on exercise or plagiarize.

(2). Requirements on teachers:

Teachers shall comment on and correct every exercise and record the results as one of bases for scoring regular grades in the end of the term.

(3). Exercise quantities:

The exercise quantities shall be suitable; that is, 3 to 5 subjects will be allocated for every two class hours.

c. Examination Methods

(1). This course is an examination course, so closed-book exam shall be carried out in final examination.

(2). Questions shall be formulated unifiedly according to test question database in final examination.

(3). Grade in final examination shall account for a main factor of 80% of overall grade; while test grade in normal times (including exercise and learning status) shall account for 20%.

E. **Recommended Teaching Materials and Bibliographies**

1. *Inorganic and Analytical Chemistry (Second Version)*, edited by Ni Jing'an, etc, ISBN 7-5025-6865-4, Chemical Industry Press, 2005
2. *Answer on Questions of and Thinking on Inorganic and Analytical Chemistry*, edited by

Zhang Jingqian, ISBN-7-5632-1275-2, Dalian Maritime University Press

3. *Solutions to Problems of Inorganic and Analytical Chemistry*, edited by Zhao Zhongyi, ISBN-7-5609-2515-4, Huazhong University of Science and Technology Press