CHEM1.5: GENERAL CHEMISTRY II

I. Course description:

1. **Credit points**: 3 ECTS
2. **Time commitment:**

Items	Lecture	Tutorial	Practical	**Total**
No. of hours	21	9	0	**30**

3. **Prerequisites:** High school chemistry
4. **Recommended background knowledge:** High school chemistry and physics
5. **Subject description:** Chemical Physics
6. **Objectives & Outcome:**

Identify the system and the surroundings in a chemical process.
Identify the ways in which energy is transferred in chemical processes.
Determine the sign of heat and work in chemical processes.
Give examples of reactions which can do work.
Calculate energies in Joules or calories.
Calculate the energy required to change the temperature
of a given mass of a material from its heat capacity.
Calculate the heat released of absorbed by a reaction from data obtained using a bomb calorimeter.
Explain the origin of the heat of a reaction.
Understand the relationship between internal energy and enthalpy.
Calculate ΔH of a reaction using Hess's Law of heat summation.
Calculate ΔH of a reaction using tables of ΔH0f.
Appreciate the origin of heat release in net bond breakage.
Explain the origin of gas expansion and heat transfer in terms of probability.
Understand the microscopic definition of entropy in terms of the number of ways of arranging a system.
Define both the 2nd and 3rd laws of thermodynamics.
Predict the entropy differences between some simple chemical systems.
Calculate ΔS of a reaction using tables of absolute entropies.
Calculate ΔSuniv or ΔG of a reaction and predict spontaneity.
Understand the relationship between ΔSuniv and ΔG.
Calculate ΔG0 based on values of ΔH0 and ΔS0 or from values of ΔG0f.
Explain the effects of temperature and pressure on ΔG.

Explain in principle how one maximises the useful work obtainable from a chemical reaction.

Explain why reaction rate depends on concentration, physical state, and temperature.

Understand how reaction rate is expressed, and distinguish among average, instantaneous, and initial rates.

Describe the information needed to determine the rate law, and explain how to calculate reaction orders, and rate constant.

Use integrated rate laws to find concentrations at a given time, reaction order, and half-life.

Explain the effect of temperature on the rate constant (Arrhenius equation) and the activation of activation energy.

Understand collision theory, and transition state theory.

Understand elementary steps and molecularity, and be able to construct a valid reaction mechanism.

Explain how a catalyst speeds a reaction by lowering Ea, and distinguish between homogeneous and heterogeneous catalysis.

Write down the expression for K for any reaction of given stoichiometry.

Predict whether reactants or products dominate the equilibrium state based on the value of K.

Predict the spontaneous direction of a reaction based on relative values of Q and K.

Explain the relationship between K and ΔG0.

Determine the relationship between Kp and Kc for gas phase equilibria.

Write equilibrium expressions for equilibria involving pure liquids and solids.

Perform calculations to determine equilibrium concentrations from initial concentrations and the value of K.

Predict qualitatively the effects of changes in concentration, temperature and pressure on an equilibrium based on Le Châtelier's principle.

Calculate the effect of a change of temperature on K based on its ΔH0.

Explain how a catalyst speeds up the establishment of equilibrium.

Understand the basis of heterogeneous catalysis

Explain the experimental conditions of pressure, temperature and metal catalyst used industrially in the Haber-Bosch process for the synthesis of NH3.

Calculate concentrations in molarity, molality, mole fraction, % w/w and % v/v and perform dilutions.

Predict qualitatively the solubilities of gases in liquids based on their molecular structure.

Determine the sign of ΔH for the dissolution of a gas in a liquid from the temperature dependence of its solubility.

Understand the effect of pressure on the solubility of gases.

Explain the molecular origin of "the bends" and limestone caves.

Predict qualitatively the miscibilities of liquids based on their molecular structure.

Identify solutes as strong electrolytes, weak electrolytes or nonelectrolytes.

Explain the origin of vapour pressure lowering and boiling point elevation of a solvent by a nonvolatile solute.

Estimate the vapour pressure of solutions of nonvolatile and volatile solutes using Raoult's law.

Read a phase diagram.

Calculate expected freezing point depressions of solutions.

Calculate expected solution osmotic pressures.

Estimate molar masses from colligative property data.

Estimate the degree of dissociation of electrolytes from colligative property data.

Explain the origin of osmotic pressure and how it can be measured.

Explain the meaning of ideality for gases and solutions.

Predict deviations from ideal gas behaviour.

Calculate the pressure of a real gas using the van der Waals equation.

Explain the molecular origin of positive and negative deviations from Raoult's law.

Explain the principles underlying fractional distillation.

Predict which combinations of solvents would be expected to be ideal and which non-ideal.

Understand the concept of activity.

Explain the advantages of the Brønsted-Lowry acid-base definition over the Arrhenius definition.

Understand the relationships between pH, pOH, pKa, pKb and pKw.

Predict qualitatively the excess species in weak conjugate acid-base pairs at a given pH.

Calculate the pH, pOH, [H+] and [OH-] for aqueous solutions of strong acids and bases.

Predict qualitatively the relative acidities of strong acids

Calculate the pH, pOH, [H+] and [OH-] for very dilute aqueous solutions of strong acids and bases.

Calculate the pH, pOH, [H+] and [OH-] for aqueous solutions of weak acids and bases.

Calculate the pKa of a weak monoprotic acid from the pH of its solution.

Predict the sequence of strengths of acidities of weak polyprotic acids.

Predict qualitatively the pH of salt solutions.

Calculate the pH for mixtures of weak acids or bases with their salts.

Calculate the pH of solutions of hydrated metal ions.

Identify Lewis acids and bases

Explain the principle of buffering action.

Calculate the pH change expected for acid or base addition to a buffer.

Choose an appropriate buffer substance for any pH value.

Explain how to prepare a buffer solution.

Explain the buffering action of H_2CO_3/HCO_3^- in the blood.

Explain how to perform an acid-base titration.

Select an appropriate indicator for any combination of acid and base.
Predict the charge of an amino acid and its direction of migration in electrophoresis given its pI.
Explain the origins of positive and negative charges on a protein.
Predict qualitatively the change in solubility of a protein with changing pH given its pI.
Convert between concentration units of molarity and ppm.
Understand the meanings of oxidation, reduction, oxidizing agent, and reducing agent.
Balance redox reactions by the half-reaction method.
Describe the physical makeup of a voltaic cell, and explain the direction of electron flow.
Draw a diagram and write the notation for a voltaic cell.
Describe how standard electrode potentials (E0half-cell values) are combine to give E0cell.
Explain how the reactivity of a metal is related to its Eohalf-cell.
Write spontaneous redox reactions using an emf series.
Understand how Ecell is related to ΔG and the charge flowing through the cell.
Use the interrelationship of ΔG0, E0cell, and K to calculate any one of these values.
Use the Nernst equation to find Ecell.
Describe how a concentration cell works and calculate its Ecell.
Relate the electrode potential and the reaction quotient.
Understand how a battery operates.
Describe the components of primary and secondary batteries, and fuel cells.
Explain how corrosion occurs and is prevented.
Understand the basis of an electrolytic cell.
Understand the relationship between charge and amount of product.
Calculate the current (or time) needed to produce a given amount of product or vice versa.

7. Assessment/ Evaluation:

Component	Attendance + Homeworks	Exercises	Assignments	Practical	Midterm	Final
Percentage %	0	0	10	20	30	60

8. Prescribed Textbook(s):

[1] Martin S. Silberberg, *Principles of General Chemistry*, 3rd Edition, 2013 (McGraw-Hill). ISBN: 9780073402697;

[2] Steven S. Zumdahl, Susan A. Zumdahl, *Chemistry*, 9th Edition, 2014 (Brooks Cole). ISBN: 9781133611097.

II. Course content & schedule:

1. Introduction to Chemical Energetics
   First Law of Thermodynamics
   Heat and Work
   Enthalpy
   Hess's Law
   Standard enthalpy of formation
   Entropy and the Second Law of Thermodynamics
   Third Law of Thermodynamics and absolute entropies
   Entropy changes in chemical reactions
   Spontaneous processes and entropy
   Gibb's free energy
   Free energy and work
2. Chemical Kinetics
   Reaction rate
   Differential rate law
   Reaction order
   Using data to determine reaction order
   Integrated rate laws for 0th, 1st, and 2nd order reactions
   Half-life
   Activation energy
   Arrhenius equation
   Determining reaction mechanism
3. Chemical Equilibrium
   The equilibrium condition
   Rates of reaction
   The equilibrium constant, Kp and Kc
   Heterogeneous equilibria
   Uses of equilibrium constants - the reaction quotient
   Solving equilibrium problems
   Factors affecting equilibrium: Le Chatelier's principle
   van't Hoff equation
   Effects of catalysts
4. Solutions
   Factors affecting solubility: molecular shape, pressure (Henry's law), temperature
   Molarity, molality and mole fraction
   Vapour pressure of solutions
   Raoult's law
   Colligative properties: boiling point elevation, freezing point depression, osmotic pressure

Phase diagrams
Nonideal behaviour of gases and solutions

5. Acids and Bases
   Brønsted-Lowry theory of acids and bases
   Calculations involving pH, Ka and Kb
   Lewis theory of acids and bases
   Hydrolysis
   Acid-base properties of salt solutions
   Common ion effect
   Buffers
   Titrations and indicators
   Isoelectric point
6. Electrochemistry
   Half reaction
   Electrochemical cell
   Active and inactive electrodes
   Nernst equation
   Relationship between cell potential and Gibbs free energy change for a redox reaction
   Electrolysis
   Faraday's law of electrolysis

III. Reference Literature: N/A