Harvard Undergraduate Science Olympiad India
2024 Open Round
Chemistry (9th-10th Grade) Syllabus

Reference Material:
You should memorize common formulas and reactions, but you need not memorize any constants as a periodic table and all needed constants will be provided **(see the provided formula sheet at the end of this document).**

Potential Topics Covered on the Exam:
Please note that not necessarily every topic on this list will be on the exam, don't get overwhelmed! The syllabus is meant to be exhaustive of all *potential* topics that could be on the exam. A great place to start is with making sure you're comfortable with the ICSE curriculum for 9th-10th grade. It will be a difficult exam, but remember you don't need to (nor do we expect you) get a 100%! Just do your best and show us all that you've learned! Good luck and happy studying!

Advanced Topics:
For those looking to further challenge themselves, below in red are more advanced topics that may also be tested. Students are encouraged to first learn the topics that are not in red before tackling these.

This syllabus contains topics which might be covered both in the open and the in person round. The exam will have questions testing a subset and not all of these bullet points in this extensive list of topics in the syllabus.
The exam will cover material allowed for the National Standard Examination Chemistry (NSEC) exam (both Class 11 and Class 12) which can be found at: https://byjus.com/olympiad/nsec-syllabus/. However, several questions may be more difficult, however, and cover more advanced topics. We wish you a lot of good luck studying!

Inorganic Chemistry:

- Periodic Table:
  - Elements classification and properties;
    - Main group elements;
    - Transition group elements;
  - Isotopes:
    - Atomic number;
    - Mass number;
    - Relative atomic mass;
    - Radioactive decay and nuclear reactions (alpha, beta, gamma);
  - Electronic configuration of atoms and their ions:
    - Quantum numbers (n,l,m);
    - Orbital types (s,p,d);
    - Hund's rule,
    - Pauli principle;
    - Para vs diamagnetism;
    - One electron vs. multi electron atoms;
    - Orbital penetration and shielding;
    - Rydberg Equation, calculating ionization energy and energy of electron transitions;
    - Photoelectric Effect;
    - Particle in a box model;
  - Trends:
    - Trends in electronegativity;
    - Trends in ionization energy;
    - Trends in electronaffinity;
    - Trends in reactivity;
    - Trends in metallic and nonmetallic character;
    - Trends in atomic and ionic size;
- Chemical Bonds:
  - Bond Types;
  - Hybridization;
  - VSEPR theory;
    - Shapes;
    - Polarity;
    - Bond Angles;
  - Solid State Chemistry:
    - Unit Cells;
    - Metallic Bonding;

    - Molecular Orbital Theory for diatomic molecules;
    - Hard-Soft Acid-Base Model;
    - Complex Ions;
        - Ligands;
        - Chelation Effect;
        - Isomers of coordination compounds;
    - Water of hydration;
    - Oxides (their acid base properties);
- Chemical Reactions:
    - Reaction types;
    - Balancing reactions;
    - Empirical formulas;
    - Stoichiometric calculations:
        - Concentrations;
        - Mole concept via volume, mass and number of atoms;

Analytical Chemistry:

- Solutions:
    - Different concentration measurements (molarity, molality, etc.)
    - Self ionization of water;
    - Hydrolysis of salts;
    - Acidity and Basicity:
        - Arrhenius acid-base theory;
        - Bronsted acid-base theory;
        - Lewis acids and bases theory;
        - pH and pOH definitions;
        - K_a and K_b as a measure of acid and base strength;
        - Buffer solutions;
    - Solubility of Compounds:
        - Soluble, slightly soluble, and insoluble salts;
        - Working with solubility constants;
        - Saturated, unsaturated, and supersaturated solutions;
    - Raoult's Law;
    - Vapor Pressure;
    - Colligative Properties;
    - Tyndall Effect;
- Quantitative Analysis:
    - Titration indicators;
    - Titration curves;
    - Acid-base titrations;

    - Oxidation-reduction titrations;
    - Precipitation titrations;
    - Combustion analysis;
- Qualitative Analysis:
    - Flame tests;
    - Specific identification reactions for common cations and anions;

Physical Chemistry:

- Equilibrium:
    - Le Chatelier's principle;
    - Phases:
        - Ideal gas law;
        - Van der Waals gas law;
        - Clausius-Clapeyron equation;
        - Phase diagrams;
        - Boiling point elevation and freezing point depression;
    - Equilibrium concept:
        - Equilibria expressed in terms of relative concentrations;
        - Equilibria expressed in terms of partial pressures;
        - Relationship between equilibrium constants and Gibbs' free energy;
        - Relationship between equilibrium constants expressed via concentrations, pressures, and mole fraction;
        - Solubility product;
        - Relevant calculations;
- Kinetics:
    - Kinetic Molecular Theory;
    - Reaction rate:
        - Order of reactions;
        - Equations of reactions;
        - Reaction rate constants;
        - Rate Laws;
        - Reaction energy profiles;
        - Relation between half-life and rate constant;
        - Steady-state approximation;
        - Relevant calculations;
    - Factors influencing reaction rate:
        - Catalyst effects;
        - Concentration effects;
        - Temperature effects;

- Thermodynamics:

- First law of thermodynamics:
  - Energy, heat and work;
  - Systems and its surroundings;
- Second law of thermodynamics:
  - Entropy and standard entropy changes;
  - Enthalpy and standard enthalpy changes;
    - Standard enthalpy of formation;
    - Standard enthalpy of phase transitions;
    - Enthalpy changes for bond dissociation;
    - Hess's Law;
    - Born-Haber Cycle;
    - Lattice Energy;
  - Gibbs' free energy and standard Gibbs' free energy changes;
    - Relationship between entropy, enthalpy and Gibbs' free energy;
    - Relationship between equilibrium constants and Gibbs' free energy;

- Electrochemistry:
  - Identifying oxidizing and reducing agents;
  - Voltaic and electrolytic cells, and cell diagrams.

Organic Chemistry:

- General Concepts:
  - Nomenclature;
  - Structures;
  - Arrow Pushing Mechanisms;
  - Conformational Analysis;
  - Stereochemistry and Chirality
- General Reactions:
  - Radical Reactions;
  - Electrophilic Addition;
  - Electrophilic Substitution;
  - Nucleophilic Addition;
  - Nucleophilic Substitution;
  - Elimination Reactions;
- Functional Groups:
  - Acidity and Basicity of common functional groups;
  - Alkanes, Alkene and Alkyne chemistry;
  - Aromatic compounds chemistry;
  - Halogen compounds chemistry;
  - Alcohol, Ether, and Epoxide chemistry;
  - Nitrogen compounds chemistry

    - Carbonyl compounds chemistry;
- ^{13}C NMR and ^{1}H NMR;
- IR Spectroscopy;
- Mass Spectrometry;
- Organic Synthesis;

Laboratory Skills:

- Choosing appropriate materials for common lab task;
- Identifying correct procedures for common lab tasks;
- Error analysis.

Preparation for Exam:

Resources and textbooks used to prepare for the NSEC exam can be found online and will be helpful to prepare for the HUSO India Exam. Having strong command of high school and ISC level chemistry is important. In general, reading a university-level **general** chemistry textbook (eg. Zumdahl Chemistry) and supplementing it with relevant chapters from a university-level organic chemistry book (eg. Klein Organic Chemistry) will aid students in preparation. In addition, it is recommended to review past NSEC papers (available online). Organic chemistry is not weighted that highly in the exam, so it is recommended to first learn general chemistry well before devoting significant time to organic chemistry. **Preparation for ISC Class 11 and Class 12 material will be strong preparation for the HUSO India exam**. **However, there will be some difficult questions that will challenge even the brightest of students!**

Formula Sheet Provided for both 7th-8th Grade and 9th-10th Grade Chemistry Exams:

CONSTANTS:

$h = 6.626 \times 10^{-34}$ J·s

F = 96485 C/(mol e^-)

$c = 2.998 \times 10^8$ m/s

R = 8.314 J/(K·mol) = 0.08206 L·atm/(mol·K)