Chemistry Topics for UIL

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2017–2018

Because this is my first year as Chemistry Director, I will continue the practices set in place by Dr. McCord, with only the two minor changes noted below, to help ensure a smooth transition for coaches and students.

I don't know if significant digits were included along with measurements in the Fundamentals section on past years' exams, but I have added them because significant digits will play a role in the answers on the 2017–2018 exams. I have also removed *Chemical Principles: The Quest for Insight* by Atkins and Jones from the reference textbooks and replaced it with *Chemistry: A Molecular Approach* by Nivaldo Tro. However, none of the actual listed reference texts are necessary in order to prepare for the exams. Test questions are never taken directly from any textbook.

Here are the topics that will be covered in the Chemistry section of the UIL Science Exams. As in previous years, the Invitational A and B exams will not include questions from Topics 12 and 13.

1. Fundamentals
2. Stoichiometry
3. Atomic Theory
4. Chemical Bonding and Structure
5. Gases
6. Liquids and Solids
7. Thermodynamics
8. Physical Equilibria
9. Chemical Equilibria
10. Acids and Bases
11. Solubility Equilibria
12. Electrochemistry
13. Chemical Kinetics

1 - Fundamentals

Measurements, significant digits, fundamental SI units, metric prefixes, unit conversions, classification of matter, the mole, concentration terms, isotopes, accuracy vs precision, extensive vs intensive properties, physical vs chemical properties.

2 - Stoichiometry

Composition: chemical formulas, empirical formula, formula units, molar mass, percent composition, nomenclature, ionic compounds, covalent compounds, first 10 hydrocarbons (alkanes), grams to moles and vice versa.
Reaction: types of chemical reactions, balancing reactions, predicting amounts of products, limiting reactant, percent yield.
Tie-ins to other topics: calculating moles from pressure/volume of gases, calculating concentrations of solutions in percent by mass, molarity, molality, ppm, ppb, and mole fraction.

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3 - Atomic Theory

Parts of the atom. Relative size of atoms. Electromagnetic radiation, frequency, wavelength, energy of one or more photons, Planck's constant. Photoelectric effect, work function of a metal. Quantum theory, line-spectra (emission and absorption), energy levels within the atom (Rydberg equation). Quantum numbers and the rules for each of them. The relative size and shapes of the atomic orbitals of hydrogen. Aufbau principle, Hund's rule, Pauli exclusion principle. Writing electron configurations for atoms and monatomic ions.

Periodic Table: names of groups 1A, 2A, 7A, and 8A (or 1, 2, 17, and 18), trends of physical and chemical properties of the elements. Ionization energy, electron affinity, electronegativity, atomic radii, ionic radii, metallic character.

4 - Chemical Bonding and Structure

Octet rule, Lewis structures (dot and line), bond order, incomplete octets, expanded octets. VSEPR Theory and electronic and molecular geometries of molecules and ions (shapes, names, angles).

Valence Bond (VB) or Localized Electron (LE) theory of bonding: hybrid orbitals and their shapes and angles. Sigma and pi bonding. Molecular orbital (MO) theory. Bonding orbitals and anti-bonding orbitals. Bond order in MO theory. Molecular polarity, dipole moment. Interpreting organic line structures.

5 - Gases

Gas laws: Boyle's, Charles', Avogadro. Combined gas law, the Ideal Gas Law.

Gas mixtures: Dalton's Law of Partial Pressures.

Gas behavior: kinetic molecular theory. Root-mean-square velocity of a gas particle (v_{rms}). Diffusion and effusion of gases. Real gas behavior and its deviation from ideal behavior, the van der Waals equation for real gases.

6 - Liquids and Solids

The condensed states – intermolecular forces (IMFs): dipole-dipole, H-bonding, and dispersion forces. Physical property trends and their relation to IMFs.

Properties: melting point, boiling point, viscosity, surface tension, and vapor pressure. Lattice energies of solids (crystals).

7 - Thermodynamics

First Law: heat and work, internal energy, enthalpy. Calorimetry, thermochemistry, heats of reaction, heats of combustion. Endothermic vs exothermic reactions. Work of an expanding gas. Second Law: spontaneity and entropy. Defining entropy. Gibb's Free Energy and spontaneous changes. Equilibrium and free energy.

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8 - Physical Equilibria

Enthalpies (heats) of transition (fusion, vaporization, sublimation, condensation,…). Entropy of these changes. Free energy change during these transitions. Phase diagrams. Colligative properties: vapor pressure lowering (Raoult's Law), freezing point depression, boiling point elevation, and osmotic pressure. The van't Hoft factor (i) – how it relates to strong electrolytes and weak electrolytes.

9 - Chemical Equilibria

The equilibrium constant, K. Using K. K_c and K_p. The form of K_c. The reaction quotient, Q. LeChatlier's Principle – predicting rxn direction of reactions under a set of conditions, stressing a reaction and predicting change. ΔG vs K. Heterogeneous equilibria.

10 - Acids and Bases

Strong vs weak acids and bases. The definition and use of pH. Ionization constants for weak acids (K_a) and bases (K_b). Calculating pH. Buffer solutions: defining a buffer, common ion effect, calculating pH of a buffer solution, LeChatlier's and buffers (response to acid or base additions). Titrations: calculating the pH during a titration (strong or weak acids and bases), pH at the equivalence point. Indicators: how they work, determining the color of an indicator and its use as an end point for titrations.

11 - Solubility Equilibria

Determining molar solubility from K_{sp} and vice versa. Calculating concentrations of species for solubility equilibria. Common ion effect for solubility. Other conc terms like ppm. Fractional (or selective) precipitation calculations. Complex ion formation and the formation constant, K_f.

12 - Electrochemistry

Identifying redox reactions. Balancing redox reactions in acid or base solution. Definitions: anode, cathode, voltaic cell, electrolytic cell, electric current, electrolytic current, the faraday constant, oxidation, reduction, oxidizing agent, reducing agent, salt bridge, standard electrode potential (E), volts, standard cell potential, non-standard cell potential (use Nernst equation). Batteries: primary vs secondary vs fuel cells. Know the fundamentals of a lead storage battery (aka: a car battery).

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13 - Chemical Kinetics

Defining the rate of a reaction. Units for reaction rates. Writing the reaction rate law equation. The specific rate constant and its units. Reaction order. Using tabulated data and using the Method of Initial Rates to determine the rate law for a reaction. The integrated rate laws for zero, first, and second order reactions. Half-life and its calculation. Reaction mechanisms: writing elementary steps for a reaction. Writing rate laws for elementary steps. Importance of the rate-limiting step. Potential energy diagrams for kinetic reactions (aka reaction profile) - interpreting activation energy of the forward and reverse reactions. Multi-step reaction schemes. Temperature effects on the rate (Arrhenius equation). How catalysts work and their effect on reaction rates - and how it changes the potential energy diagram.

Approximate Question Distribution/Difficulty for Each Exam

Invitationals A & B

Topics 1-11 (no 12 or 13) with emphasis on 1 and 2. Generally these 2 exams will have the easiest types of questions. Very straight forward information and calculations.

District

All topics are possible (1-13) here. The questions will go a little deeper into the subject matter. Some problems will be complex in nature but overall, this is a notch down in difficulty from the regional and state exams.

Regional and State

Once again, all topics will be covered (1-13). Any problems from 1 and 2 will be more complex than on previous exams - often a multi-step solution. All other topics will be at a more advanced level. Equilibrium problems will require more algebra to solve them. Of course the state exam will be the hardest of all the exams. Most of the calculations on the state exam will require a few calculation steps and not just one.

In general both the number and the difficulty of the calculational problems will increase as the student progresses from Invitational to District to Regional to State.

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Some Textbook References and Web References for Chemistry

College Textbooks
Remember that you can use much older editions to save money and not really lose any content. Newer editions will have more web references and "nice" things but all the core material is in the editions going back 10-20 years. Realize that there are many other good textbooks out there besides those listed here.

Chemistry: The Central Science by Brown, LeMay & Bursten
General Chemistry (old name – up to 7th ed) by Whitten, Davis & Peck
Chemistry (new name as of 8th ed, 2006) by Whitten, Davis & Peck
Chemistry: A Molecular Approach by Tro
Chemical Principles by Zumdahl (& Decoste)

Website References
University of Texas at Austin (Department of Chemistry)
https://gchem.cm.utexas.edu

(This is really just a combination of the ch301 and ch302 sites below - all new content goes here.)

The older sites still work but might be removed in the future:
https://ch301.cm.utexas.edu
https://ch302.cm.utexas.edu

OpenStax College (Rice)
This is a free downloadable chemistry textbook in pdf format.
https://openstaxcollege.org/textbooks/chemistry