Associate of Arts in Secondary Teaching

Content Area: **Chemistry**

There has been a significant national reform movement in science education in the United States over the last decade. This reform has emphasized the fundamental importance of science literacy for a vibrant society, the need for students at all levels to be able to use scientific principles and processes meaningfully, and the critical role of the student in the learning process (constructivism). Standards and plans for action have been delineated in the documents National Science Education Standards (1996) and College Pathways to the Science Education Standards (2001).

The outcomes listed below address the following national standards for students and teachers of chemistry:
    A) National Science Education Standards
            Content Standards in Chemistry K-12
            Professional Development of Teachers of Science: Standard A
    B) National Education Technology Standards for Students: 2, 3, 5, 6

The outcomes include all information required for the Praxis II Subject Assessment in Chemistry.

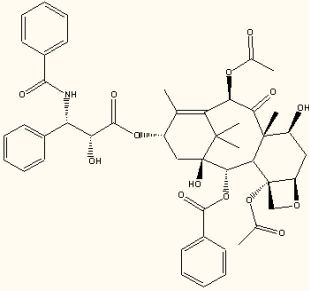| OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
1. Make measurements and express those measurements in common and metric units; manipulate units	a) Make measurement; b) convert measurements between systems	Short answer Problem solving Performance	1. Convert 3.2 lb/gal to g/mL. 2. Given an object, determine its mass and volume and express the resulting density in units other than those measured.
2. Understand and apply significant figures and exponential notation to measurement	a) Correctly express numbers in scientific notation with appropriate significant figures	Short answer Performance	1. Given an object, determine the mass and volume and express the resulting density in units other than those measured. Answer must be expressed to the correct number of significant figures and in exponential notation.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
3. Understand nature of science and scientific investigation	a) Design, conduct, evaluate and/or interpret a scientific investigation	Essay	1. You are presented with the question, "Does the volume of a gas depend on its temperature?" Determine how you might answer the question in an experimental manner. Include a hypothesis, list of independent, dependent and controlled variables, a basic experimental design and observations that may be anticipated.
4. Distinguish among states of matter; explain behaviors of states based on particulate nature	a) Identify state; b) give characteristics of each state; c) explain behavior of state	Short answer Essay	1. In the sealed flasks below, using small circles to represent particles, sketch benzene at -10°C (solid) and $25\,^{\circ}$C (liquid).
5. Know basic atomic structure; understand historical development of atomic theory and its relationship to spectroscopy	a) Identify characteristics of sub-atomic particles; b) know important contributions to modern atomic theory; c) relate atomic composition to element identification and isotopes; d) relate to modern spectroscopy	Short answer Essay	1. Explain what information the gold foil experiment provided about the nature and structure of the atom. Include how the experimental results led to the conclusions obtained. 2. Explain the cause of spectral lines and why they are different for each element.
6. Understand principles of the quantum mechanical model of the atom	a) Recognize types and characteristics of atomic orbitals; b) generate and interpret electron configurations	Short answer	1. What Period 2 element has exactly three p orbital electrons in its shell?
7. Understand the development of and trends conveyed by the periodic table of the elements	a) Use the periodic table to obtain and predict elemental properties such as relative atomic size, ionization energy, electron affinity, and electronegativity.	Short answer Essay	1. If a new element was discovered that should be placed under francium on the periodic table, what would its properties be?

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
8. Understand the concept of bonding as resulting from electron interactions; understand bond nature as a continuum	a) Distinguish between ionic and covalent bonding; b) give example of each type of bond; c) explain why bond character may not be purely ionic or covalent; d) identify dipole moment in bonds; e) draw Lewis dot structures	Short answer Essay	1. Draw a Lewis dot structure for NO_2^{1-}. 2. A general statement says that metals and non-metals form ionic bonds. However, MnO_2 has characteristics consistent with a covalent bond. Explain why.
9. Visualize geometries of molecules; apply VSEPR theory and hybridization theory	a) Predict geometries of molecules and know hybridization of atoms in a molecule	Problem solving	1. Determine the molecular geometry of SO_2. 2. Sketch CH_4.
10. Determine molecular polarity as it relates to geometry; understand properties dependent on molecular polarity	a) Determine if molecule has dipole moment; b) know types of intermolecular forces; c) explain how properties such as boiling point and solubility are related to intermolecular forces.	Short answer Problem solving	1. Is CH_2Cl_2 a polar molecule? Why or Why not? 2. Explain why methyl ether (CH_3OCH_3) is a gas at room temperature while ethyl alcohol (CH_3CH_2OH) is a liquid.
11. Understand concept of chemical change as a chemical reaction; know types of chemical reactions	a) Identify types of reactions; b) recognize process as a chemical change	Short answer Performance	1. Heat a sample of $CuCO_3$ over a Bunsen burner for 5 minutes and cool. Based on your observations, determine if the change is chemical or physical. Explain your reasoning.
12. Understand chemical nomenclature	a) Write formula for chemical compounds; b) write names from formulas; c) write and interpret chemical equations; d) balance chemical equations	Short answer	1. Complete and balance the following chemical equation: $AgNO_3$ (aq) + $BaCl_2$ (aq) →

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13. Understand the mole concept and stoichiometry	a) Calculate molar mass, moles, empirical formulas, % composition, mole ratios, number of particles; reactant and product amounts	Problem solving	1. $C_3H_8O_2 + O_2 \rightarrow CO_2 + H_2O$ If you start the above chemical reaction with 50.0 g of $C_3H_8O_2$ and 75.0 g of O_2, how many grams of water could be produced? If you obtain 27.0 grams of water, what is the % yield?
14. Know characteristics and processes of solutions	a) Calculate concentration (molarity, molality, % solution, etc); b) explain processes of dissolving a solute; c) explain the interactions between solutes and solvents; d) use solubility rules; e) explain colligative properties	Short answer Problem solving Essay	1. Determine the molarity of a solution made by adding 35.5 g of Na_2SO_4 to enough water to form 750 mL of solution. 2. You have a 1.0 M solution of NaCl and 1.0 M solution of $CaCl_2$. Explain how the boiling point of the NaCl solution compares to the boiling points of pure water and the $CaCl_2$ solution and why.
15. Know physical and chemical properties of acids and bases	a) Identify acids and bases; distinguish among characteristics of acids and bases; b) know different definitions of acids and bases; c) calculate and interpret pH for weak and strong acids and bases; d) explain buffer systems and calculate pH of buffer systems	Short answer Problem solving Essay	1. Calculate the pH of a 0.023 M solution of HCl. 2. Explain how the bicarbonate-carbonic acid buffer system maintains pH upon a) addition of an acid and b) addition of a base.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
16. Understand reaction equilibria	a) Identify characteristics of a variety of equilibrium system including Le Chatelier's principle; b) calculate K and equilibrium concentrations	Short answer Problem solving Essay	1. Given the K_b for ammonia, calculate the pH of a 0.10 M solution of aqueous ammonia. 2. Consider the following equilibrium system: $2 N_2 (g) + O_2 (g) \leftrightarrow 2 N_2O (g)$ Explain what happens to the concentration of N_2O when: a) pressure is doubled by halving the volume b) N_2 is added c) O_2 is removed
17. Understand interactions of matter and energy	a) Explain the effect of absorption or release of energy on a system	Short answer Essay	1. Why does a hydrogen atom absorb only certain wavelengths of light? What happens when this absorption occurs?
18. Understand concept of heat exchange in physical and chemical systems	a) Employ specific heat and ΔH of a material to calculate heat transfer; b) apply calorimetry to measure heat exchange; c) interpret phase diagrams and heating/cooling curves	Short answer Essay Problem solving Performance	1. Using a coffee cup calorimeter , determine the specific heat of a metal.
19. Interpret thermodynamics of a chemical system	a) Be able to calculate and use $\Delta H, \Delta S, \Delta G, K$ to characterize a reaction	Problem solving Essay	1. The net reaction for the corrosion of iron is: $4 Fe (s) + 3 O_2 (g) \rightarrow 2 Fe_2O_3 (s)$ From the data below, calculate the equilibrium constant at 25^oC. Substance ΔH^o_f (kJ/mol) S^o J/K·mol Fe_2O_3 (s) -826 90 Fe (s) 0 27 O_2 (g) 0 205

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20. Understand components, structure, and function of an electrochemical cell	a)Identify components of a cell; b) distinguish between galvanic and electrolytic cells; c) calculate cell EMF and apply Faraday's law; d) balance redox reactions	Short answer Problem solving Essay Performance	1. On the cell illustrated, label the components. Determine the direction of electron flow and the cell EMF.
21. Know nuclear reactions, including radioactivity, fission and fusion	a) Interpret, complete nuclear reactions; b) know characteristics of nuclear emissions; c) use concept of half-life to calculate half-life or residual amounts; d) know environmental sources of radioactive emissions	Short answer Essay Problem solving	1. Complete the following nuclear reaction: _____ + ^4_2He → $^{243}_{97}\text{Bk}$ + ^1_0n 2. The half-life of phosphorus-32 is 14.3 days. What mass of P-32 is left after 35.0 days from an original sample of 175 mg of $\text{Na}_3{}^{32}\text{PO}_4$?
22. Interpret kinetics for a chemical system	a) Determine rate constant and rate law from experimental data; b) determine reaction order and relate this to reaction mechanism	Short answer Problem solving Essay	1. Explain why the rate of a reaction increases as temperature increases. 2. Using the data for initial reactant concentrations and measured initial rates for the trials listed, determine the rate law for the equation provided. Is the following mechanism consistent with your rate equation? Explain.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
23. Know the structure, function, and nomenclature of functional groups	a) Identify a functional group; name molecules based on functional group; b) know structure of organic molecules based on functional group	Short answer Essay	1. Identify the functional groups in taxol. 2. Draw the structure of 3,3-dimethyl-4-oxohexanoic acid.
24. Understand free-radical reactions.	a) Write a mechanism for a free radical chain reaction; b) explain the selectivity of a free radical reaction.	Essay Short Answer	1. Write the mechanism for the free-radical destruction of ozone in the stratosphere. 2. What is the major product seen in the free radical bromination of 2-methylpropane? Explain.
25. Interpret reaction mechanisms	a) Write a mechanism for a specific reaction such as S_N1, S_N2, E1, Diels-Alder	Problem solving Essay	1. The reaction of cyclopentyl bromide with sodium cyanide to give cyclopentyl cyanide proceeds faster if a small amount of NaI is added. Suggest a reasonable mechanism to explain the catalytic function of the NaI.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
26. Understand principles of stereochemistry	a) Discuss how bonding and electron pair geometry affect molecular rigidity and flexibility. b) identify chiral centers, enantiomers, diastereomers, racemic mixtures; c) determine absolute configuration; d) determine configuration based on reaction mechanism	Short answer Problem solving Essay	1. Generate the energy versus dihedral angle graph for single bond conformations of butane. 2. Which molecule is the least stable (has the highest energy) *cis*-1,3-dimethylcyclohexane or *trans*-1,3-dimethyl cyclohexane. Explain 3. What is the configuration of the product of the reaction of bromine with *cis*-2-pentene?
27. Understand spectroscopic principles for structure determination	Interpret infrared, UV, proton and ^{13}C NMR, and mass spectroscopy spectra to determine molecular structure	Short answer Problem solving Essay Performance	1. Given the proton NMR spectrum, ^{13}C NMR spectrum, mass spectroscopy peaks, and IR spectrum, determine a reasonable structure for your unknown. 2. Given the relative % intensities of the MS peaks, determine the molecular formula of the unknown (CH_3CH_2Br is an example)
28. Understand electrophilic addition reactions in alkenes and alkynes.	a) Beginning with appropriate starting material, show the steps to make alkenes and alkynes; b) use appropriate reagents to convert alkenes and alkynes into other functional groups	Problem solving Performance Essay	1. Predict the major and minor products resulting from the dehydration of 1, 2-dimethylcyclohexanol. 2. Starting with 1-hexyne, outline the syntheses of 2-hexanone and hexanal.

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29. Understand principles of organometallic chemistry.	a) Outline a Grignard synthesis; b) use butyl lithium or LDA as a base or as a synthon	Problem solving. Performance Essay	1. Design and execute the synthesis of 2-methyl-2-hexanol using a Grignard synthesis. 2. What is the major product of the reaction of 2-cyclopentenone and butyllithium? 3. Predict the major product of the reaction of LDA with 3-methyl-2-butanone at (a) 78^oC and (b) 250^oC, followed by reaction with methyl iodide at the same temperature and EXPLAIN your answers.
30. Understand oxidation/reduction reactions of organic molecules.	a) Recognize oxidation states of organic molecules; b) Design syntheses using oxidation or reduction of organic molecules	Problem Solving Performance Essay	1. Outline the mechanism of the sodium borohydride reduction of cyclohexanone. 2. What is the starting alkene if the products of oxidative cleavage using ozone/dimethylsulfide are pentanal and acetone, what is the starting alkene? 3. Beginning with 1-hexanol, outline the synthesis of hexanal.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
31. Understand principles of aromaticity and the reactions of conjugated systems.	a) Determine aromaticity/non aromaticity/antiaromaticity of a system; b) understand and utilize Diels Alder reaction for synthesis; c) understand describe mechanism of electrophilic aromatic substitution and direction influences of substituents; d) understand and utilize allylic substitution and 1,4- addition	Problem Solving Performance Essay	1 .Identify which of the following compounds is aromatic: cyclobutadiene, cyclopentadienyl anion, pyran 2. Predict the major product of the reaction of tert-butyllithium with 1-methylcyclopropene. 3. Show a Diels-Alder route to 4,5-dimethylcyclohexene. 4. Outline the mechanism of the formation of 4-bromoacetanilide from acetanilide with bromine and iron.
32. Design and carry out multistep syntheses	a) Starting with a reactant show steps to achieve product; b) complete a laboratory multi-step synthesis	Problem solving Performance	1. Outline a synthesis for the conversion of the 1-butyne to 3-hexanone. Include all necessary reagents. Show the structures of all intermediate compounds. Show the retrosynthetic analysis of the problem.
33. Recognize and characterize biologically important molecules	a) Identify carbohydrates, proteins and amino acids, lipids, nucleic acids; b) know classifications, and functions of biomolecules	Short answer Performance	1. You are given an unknown that could be a protein, lipid, or carbohydrate. Using laboratory tests, determine what the unknown is. Document your results and justify your conclusion.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
34. Carbonyl group chemistry, including alpha substitution reactions and enol condensations.	a) Predict the products of the reactions of common nucleophiles with the carbonyl group of aldehydes, ketones and carboxylic acid derivatives. b) predict the products of substitution and aldol-type reactions at the carbon alpha to the carbonyl group of aldehydes, ketones and carboxylic acid derivatives.	Problem solving Performance Essay	1. Show how the alpha and beta forms of glucopyranose can be interconverted in solution. 2. Show how glucose can be converted to fructose in a solution of weak base.
35. Amine Chemistry	a) Know the methods of synthesizing the amine functional group. b) account for the basicity and nucleophilicity of amine chemistry	Problem solving Performance Essay	1. Show two methods to synthesize sec-butylamine. 2. Explain why the isoelectric point of lysine is at a pH of about 9.
36. Polymer Chemistry	a) Know how to classify polymers as chain-growth, copolymers or, step-growth polymers. b) know how to classify based on physical properties	Problem solving Performance Essay	1. Explain the use of the Ziegler-Natta catalyst in alkene polymerization.
37. Utilize tools for the collection of data	a) Prepare samples and use appropriate equipment to collect data. Equipment should include spectrophotometer, pH meter, volumetric glassware, IR, GC, analytical balances, melting point apparatus, software packages	Performance	1. Using a visible spectrophotometer, determine the absorbances of a series of standards and unknowns.

OUTCOMES Teacher candidates will be able to:	INDICATORS	ASSESSMENT TYPE	SAMPLE ASSESSMENT TASKS
38. Analyze and interpret experimental data	a) Draw appropriate conclusion from analyzed data	Problem solving Performance	1. Determine the concentration of a colored unknown using concentrations and absorbances of standards. 2. Using a spreadsheet or statistical application and empirical data, explore the relationship between two variables affecting a system. Give a reasonable explanation for what is occurring in the system.
39. Demonstrate safe laboratory practice	a) Use safe laboratory practices	Short Answer Performance	1. Identify the location and purpose of all safety equipment in this laboratory. 2. May be assessed by assigning points for adherence to correct laboratory behavior such as wearing eye protection, disposing of chemicals correctly, handling glassware and other equipment safely, following instructions carefully.
40. Demonstrate basic laboratory techniques	a) Use basic techniques such as solution preparation, distillation, titration, recrystallization, filtration	Performance	1. Given a mixture, separate and purify a mixture using appropriate laboratory techniques.
41. Know and understand the relationship of science to other human values and endeavors	a) Use principles of chemistry to address topics of significance to society	Essay	1. At the completion of an experiment you are required to dispose of all materials in properly labeled containers. Explain the possible impact of pouring the materials down the drain.

Additional Notes:

1. To become a teacher of chemistry at the secondary level, a candidate must meet the requirements for the completion of a bachelor's degree in chemistry. During the first two years of study for this degree a student is expected to meet the above outcomes. These will be met if a student successfully completes General Chemistry I and II (8-10 credits) and Organic Chemistry I and II (8-10 credits). However, it is important that an academic institution review its General Chemistry and Organic sequences to ensure these outcomes are addressed. Survey courses in General or Organic chemistry will not have the sufficient depth to meet these outcomes.

2. In addition to the chemistry outcomes, a candidate for this degree will need to complete the following courses in the first two years:

Mathematics: 2 semesters of calculus designed for mathematics, physical science, and/or engineering majors

Physics: Track 1: 2 semesters of calculus-based physics (all institutions)

or

Track 2: 2 semesters of algebra-based physics which is acceptable at <u>only</u> the following: Columbia Union, Goucher, Frostburg, Hood, or Towson

3. Some academic institutions to which a candidate may transfer require additional chemistry preparation in the form of a one to four credit course in laboratory techniques and/or safety or descriptive chemistry and possibly a biology course. These must be taken in the junior year at the transfer institution.

<u>College Pathways to the Science Education Standards</u>, NSTA Press, Washington, D.C., 2001

<u>National Science Education Standards</u>, National Academy Press, Washington, D.C., 1996

Technology Foundation Standards for All Students, <u>http://cnets.iste.org/sfors.htm</u>, November 2001