

Chem 222 Study Guide
Miessler, Fischer, and Tarr 5th ed.
Lagowski and Sorum 8th ed.

Recommended Problems from Miessler: Tier 1 = highly suggested Tier 2 = lightly suggested

Ch. 2 (Atomic Structure): Read sections 2.2.2 through the rest of the chapter.

Recommended Problems: Tier 1: 9, 15, 18, 19, 22, 38, 42. Tier 2: 10, 23, 28, 33, 39, 43, 44.

Terms

Radial wave functions	Aufbau Principle
Radial probability functions	Pairing energy - Coulombic repulsion vs. exchange energies
Orbitals and their shapes	Screening/shielding effect
Nodes radial and angular	Effective nuclear charge
Quantum numbers: n , l , m_l , m_s - What do they describe? What possible values do they have?	Slater's rules
Shielding/Screening of electrons in outer shells - What does this affect?	Atomic radii and their trends
Pauli Exclusion Principle	Ionic radii and their trends
Hund's Rule	Ionization Energies and their trends
	Electron Affinities and their trends

Concepts and Skills

Be able to sketch radial wave functions (in 1-D), and radial probability function (in 1-D and 2-D)

Understand how orbitals are arranged in terms of energy within an atom

Calculate the pairing energy in an atom and which electron arrangement is preferred

Calculate the effective nuclear charge of a given electron in an atom

Ch. 3 (Molecular Structure): Read sections 3.1 and 3.2 (except section 3.2.4).

Recommended Problems: Tier 1: 9, 13, 17, 20, 29. Tier 2: 1, 2, 4, 8, 10, 12, 14, 41, 42.

Terms

Lewis dot structure	Bond angles
Octet rule/suggestion	Electronegativity
VSEPR theory	

Concepts and Skills

Draw Lewis dot structures of molecules and ions, including ones that violate the octet rule

Draw all reasonable resonance structures of a molecule or ion

Calculate the formal charge on an atom in a Lewis Structure

Determine the electron-pair geometry and molecular geometry (shape) of a given molecule or ion

Know bond angles of given geometries, including with the influence of lone pairs

Decide whether a molecule is polar or non-polar

Understand the influence of sterics vs. electronegativity in terms of bond angles

Ch. 5 (Molecular Orbital Theory): Read sections 5.1-5.3.

Recommended Problems: Tier 1: #1, 2, 3, 5, 10. Tier 2: #4, 8, 12, 13 (no calculation required).

Terms

Linear combination of atomic orbitals (LCAO)	Gerade vs. ungerade
Orbital overlap	Paramagnetic vs. diamagnetic
Sigma bonding and antibonding orbitals	Bond order
Pi bonding and antibonding orbitals	Frontier orbitals - HOMO and LUMO
Delta bonds	Photoelectron spectroscopy
Mixing	

Concepts and Skills

Draw molecular orbital diagrams of homonuclear and heteronuclear diatomics

Understand why MO theory is important

Understand the influence of energy and orbital overlap in bonding
Recognize which orbitals can form bonds (and which ones cannot!)
Know the difference between the N₂ orbital and O₂ orbital arrangements

Silver Group Recommended Problems

Lagowski & Sorum *Chapter 9*: 9, 11, 15

Copper-Arsenic Group Recommended Problems

Lagowski & Sorum *Chapter 10*: 10, 18, 22

Ch. 6 (Acid-Base Theory): Read sections 6.1, 6.2, 6.3, 6.4 (subsections 1, 6, 7) 6.6 (subsection 1).

Recommended Problems: Tier 1: #1, 6, 25, 30, 34, 35, 36, 37, 39. Tier 2: #2, 19, 21, 23, 24, 26, 38.

Ch. 3 in Lagowski & Sorum (except buffers) **Recommended Problems**: 3.1 (acegi), 3.3, 3.4, 3.15 (a,c).

Acid-Base Chemistry

Terms

Arrhenius definitions	Acidic, basic, neutral salts
Bronsted-Lowry definitions	Hard-soft acid-base theory
Conjugate acid-base pairs	Basolo rule
Autoionization	Acid-base structural trends – what make an acid (or base) stronger based on structure
pH	Acid-base properties of metal ions in water
K _a , K _b , K _w	Steric effects vs. induction (electronegativity) effects in acids and bases
Lewis definitions	Superacid
% ionization	Superbase
amphoteric/amphiprotic	
Non-aqueous acid-base systems	
Acidic, basic oxides	

Concepts and Skills

Define which species are acids or bases by the following definitions – Arrhenius, Bronsted-Lowry, Lewis
Recognize the 6 strong acids (HCl, HBr, HI, HNO₃, HClO₄, H₂SO₄ (both protons) - HClO₃ is borderline strong)
Recognize the strong bases - soluble oxides and hydroxides except NH₄OH

$K_w = [H_3O^+][OH^-]$ calculations

pH calculations for aqueous solutions of strong acids and bases

pH from $[H_3O^+]$ and vice versa ($pH = -\log[H_3O^+]$ and $[H_3O^+] = 10^{-pH}$)

pH calculations for aqueous solutions of weak acids and bases (remember shortcut: $K_a = x^2/[HA]_{initial}$)

% ionization (for acidic and basic solutions) (% ioniz. = $([H_3O^+]/[HA]_{initial}) * 100$)

Identify acidic, basic and neutral salts

Calculate non-aqueous concentrations using K_{ion}

Understand frontier orbital interactions in acid-base chemistry

Understand hard-soft acid-base theory and how to predict bonding using it

Ch. 7 (Solid-State Theory): Read sections 7.1, Intro to 7.2 (skip sections 7.2.1 and 7.2.2), 7.3 Intro (skip sections 7.3.1. and 7.3.2), 7.4 Intro (skip sections 7.4.1-7.4.3), 7.6, 7.7.

Recommended Problems: Tier 1: #5, 7, 13, 16, 21, 33. Tier 2: #2, 12, 17.

Structure and Bonding in Solids

Terms

Crystalline vs. amorphous solid	Coordination number
Metallic vs. ionic vs. molecular vs. network solids	Common types of unit cells – NaCl, CsCl, ZnS (zinc blende, wurtzite), fluorite, antiferite, NiAs, TiO ₂ (rutile)
Network solids – 1-dimensional vs. 2-dimensional vs. 3-dimensional	Radius ratio
Allotropes	Born-Haber cycle – lattice energy
Metallic bonding and a sea of electrons	Insulator, conductor, semiconductor, superconductor
Close-packing structures – hcp vs. ccp	Band theory – conduction and valence bands, band gap
Unit cell	Semiconductors – intrinsic, doping, n-type semiconductor, p-type semiconductor
Cubic unit cells – simple, body-centered, face-centered	
Packing efficiency	

Concepts and Skills

Calculations relating the unit cell with bulk properties like density and formula

Identify substances as molecular, ionic, metallic or covalent solids

Identify how many atoms, anions or cations are in a unit cell (given a picture)

Identify the type of common unit cell given a picture (NaCl, CsCl, ZnS (zinc blende, wurtzite), fluorite, antiferite, NiAs, TiO₂ (rutile))

Identify the formula of a silicate material

Additional Recommended Problems

- Three different metals form crystals with a unit cell length $d = 291$ pm. One unit cell is a simple cubic arrangement, one is a body-centered cubic array, and the third is a face-centered cubic lattice. What is the radius of an atom in the
 - simple cubic unit cell?
 - body-centered cubic cell?
 - face-centered cubic cell?
- If the bcc unit cell above is for Fe, calculate the density of Fe in g/mL.

Aluminum-Nickel Group Recommended Problems

Lagowski & Sorum *Chapter 11*: 9, 13, 15

Barium-Magnesium Group Recommended Problems

Lagowski & Sorum *Chapter 12*: 5, 9, 12

Ch. 9 (Coordination Chemistry I: Structures and Isomers): Read sections 9.1 to 9.3 (except 9.3.6 and 9.3.8).

Recommended Problems: Tier 1: #2-4, 7, 11, 12a-b, 19b-c. Tier 2: #5a-d, 8, 9, 20.

Ch. 10 (Coordination Chemistry II: Bonding) Read sect. 10.1.1, 10.1.2, 10.2, 10.3.2, 10.3.3, 10.4.4, 10.5

Recommended Problems: Tier 1: #1, 2a-c, 8, 22. Tier 2: # 3a,c, 5, 6, 21.

Complex Ions

terms

Ligand – chelating, polydentate

18 electron rule

Inner vs. outer coordination sphere

Nomenclature using Stock system

Stereoisomers – diastereomer, enantiomer, cis/trans, fac/mer

Chelate ring isomers (Δ or Λ)

Methods to determine stereoisomers – XRD, ORD, CD

Paramagnetic vs. diamagnetic

Magnetic susceptibility and spin magnetic moment

Valence bond theory

Crystal field theory

High spin vs. low spin complex

Weak field vs. strong field ligands

Beer's Law

Spectrochemical series – know which ligands are weak or strong field ligands

Concepts and Skills

Write electron configurations for transition metal ions

Name coordination complexes and write chemical formulas from names – need to memorize ligand names

Draw structures for isomers of complex ions

Recognize diastereomers, enantiomers, and linkage isomers

Determine the isomer for chelate ring isomers (Δ or Λ)

Calculate the number of unpaired electrons from magnetic susceptibility and spin magnetic moment

Identify the hybrid orbital and shape of a complex from its Lewis structure, draw a 3D rendition of the shape

Understand the orbital diagrams for octahedral, tetrahedral and square planar geometries based on crystal field and ligand field theory

Distinguish when a 4-ligand system is square planar and when it's tetrahedral

Draw orbital diagrams for high and low spin complexes

Predict magnetic behavior (para or diamagnetic) for complexes

Understand absorbed vs. reflected light for colors of transition metal complexes, including rough wavelengths based on the color wheel

Absorption calculations with $E = hc/\lambda$

Predict trends in absorbed and reflected colors based on ligands

Determine number of unpaired electrons based on ligands

Additional Recommended Problems

- Name the following complex ions encountered in lab:
 $\text{Cr}(\text{OH})_4^{-1}$ $\text{Co}(\text{NH}_3)_6^{+3}$ $\text{Fe}(\text{SCN})_6^{-3}$ $\text{Cu}(\text{CN})_2^{-1}$
- Write formulas for the following complex ions:
pentacarbonyliron(0) dichloroargentate(I) hexafluoroferrate(III) monoaquatetrihydrozinc(II)
- Draw 3D representations of all the diastereomers of $\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3$.
- Draw 3D representations of the enantiomers of the following. In each case, would the enantiomers be expected to rotate light in opposite directions?
 CFCIBrI $\text{Cu}(\text{en})\text{Cl}_2$
- Draw the orbital diagrams (box notation electron configuration) for the high spin and the low spin complexes of $\text{Fe}(\text{CN})_6^{-4}$. Identify each as paramagnetic or diamagnetic.
- Draw the energy diagram showing the expected crystal field splitting for the following complexes:
 $\text{Ni}(\text{NH}_3)_6^{+2}$ $\text{Co}(\text{Br})_4^{-2}$

Electrochemistry: Read all of Ch. 6 in Lagowski and Sorum.

Recommended Problems: 6.1, 6.2 (a,f), 6.5, 6.6 (a,b), 6.7.

Terms

Oxidation state

Reduction/oxidation

Reducing agent/Oxidizing agent

Half-reaction

Electrochemistry

Redox couple – How is it written?

Electrochemical cell – galvanic or electrolytic

Electrode – anode and cathode – what happens at each?

Hydrogen electrode – what is it composed of and why is it important?

Cell diagram (anode|cathode)

Salt bridge – Why do we need them?

Cell potential

Standard cell potential

Standard reduction potential (for a single half-reaction)

The significance of a cell potential

Spontaneous vs. non-spontaneous reaction

Disproportionation

Passivation

The relationship between E_{cell} , ΔG_{rxn} , and K

Volts, Amperes, and Coulombs

Current

Potential energy

Electrolysis

Concepts and Skills

- Determine the oxidation state of any atom in a compound
- Balance redox reactions and half-reactions, including those based on acidic or basic solution
- Pick out half reactions from a full redox reaction and tell which is the oxidation and which is the reduction
- Write and balance overall cell reaction from half reactions
- Describe a cell using standard line notation ("cell diagram")
- Know how to draw a picture of a cell
- Predict what reactions may occur and the direction of reaction based the standard cell voltage
- Calculate standard cell voltages
- Calculations using the Nernst Equation
- Reduction potentials – know what they mean and how to use them
- Calculate ΔG_{rxn} from E_{cell}
- Calculate K from E_{cell}
- Calculate electrolysis problems (Calculations relating mass, moles, charge (coulombs), current, time)

Additional Recommended Problems

- What is the E° and balanced reaction for the cell: $\text{Fe(s)}|\text{Fe}^{+2}(\text{aq})||\text{H}^+(\text{aq}), \text{H}_2\text{O(l)}|\text{O}_2(\text{g})|\text{Pt(s)}$?
- Which is the strongest reducing agent: Fe^{+2} , Fe^{+3} , Sn^{+2} , I^- ? Explain your reasoning.
- Nitrate reduction to NO(g) occurs at 0.96 V under standard conditions. Will nitrate's strength as an oxidizing agent increase, decrease, or stay the same if the $[\text{H}^+]$ is increased to 16M?
- Copper is purified electrolytically by setting up a cell with the impure copper as the anode (oxidation) and a pure copper rod as the cathode (reduction) with aqueous CuSO_4 as the electrolyte. If a constant current of 100.0 amp is passed through the solution for 24.0 hr, how many kilograms of copper are refined (deposited on the cathode)?
- What is the reduction potential for the half cell: $\text{Pt}|\text{H}_2(0.835 \text{ atm})|\text{H}^+(\text{pH } 4.00)|?$

Anion Group and Single Salt Recommended Problems

Lagowski & Sorum *Chapter 14*: 21, 31, 32, 39a-f, 40.

Constants and Equations Supplied on Exams

Z_{eff} s/p: same $n = 0.35$, $n-1 = 0.85$, $\leq n-2 = 1.00$ d/f: same $n = 0.35$, rest = 1.00

$$0^\circ\text{C} = 273.15 \text{ K} \quad \mu = 2.828 (\chi)^{\frac{1}{2}} \quad \mu_s = [n(n+2)]^{\frac{1}{2}} \quad N_A = 6.022 \times 10^{23} \frac{\text{particles}}{\text{mole}}$$

$$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} \quad c = 2.998 \times 10^8 \frac{\text{m}}{\text{s}} \quad R = 8.314 \frac{\text{J}}{\text{K}\cdot\text{mole}} = 0.08206 \frac{\text{L}\cdot\text{atm}}{\text{K}\cdot\text{mole}}$$

$$\text{Amp} = \frac{\text{C}}{\text{s}} \quad F = 96500 \frac{\text{C}}{\text{mole}} = 96500 \frac{\text{J}\cdot\text{V}}{\text{mole}} \quad E = E^\circ - \frac{RT}{nF} \ln(Q) \quad \frac{RT}{F} = 0.025693 \text{ V}$$

$$\text{at } 25^\circ\text{C} \quad E = E^\circ - \frac{0.05916}{n} \log(Q) \quad \text{1st order } \ln\left(\frac{A}{A_0}\right) = -k t \quad t_{1/2} = \frac{\ln 2}{k}$$

$$\text{mass e} = 0.00055 \text{ amu} \quad p = 1.00728 \text{ amu} \quad n = 1.00866 \text{ amu}$$

$$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg} = 931.6 \text{ MeV}$$