SAULT COLLEGE
of Applied Arts and Technology
Sault Ste. Marie

COURSE OUTLINE

PHY-106-3

MODERN PHYSICS FOR CHEMISTRY

UIMIT 1

Atoms, lyioiecyles, and ions

The goal of this unit is to examine fundamental units of matter and to relate the properties of substances to these particles.

INSTRUCTIONAL OBJECTIVES

.1 Atomic Theory

1. State the postulates of Dalton's atomic theory.
2. State the Laws of Conservation of Mass, Constant Composition, and Multiple Proportions.
3. Relate the Postulates of Dalton's theory to these laws.

*4. Illustrate the Law of Multiple Proportions when given weight analysis data for two or more compounds of two elements. (Prob. 2.1)

.2 Components of the Atom

1. Summarize the experimental work of Thomson, Milliken, and Rutherford and state the conclusions resulting from their work.
2. List the charges and relative masses of a neutron, a proton, and an electron.
3. Recognize the existence of isotopes and the nuclear differences between the isotopes of an element.

*4. Illustrate the relationship of atomic number and mass number to the number of protons, neutrons, and electrons. (Prob. 2.2)

.3 Molecules and lons^

1. Distinguish between atom, molecule, and ion.
2. Explain how cations and anions are formed from atoms.

.4 Relative Masses of Atoms

1. Define atomic weight and explain its meaning.
2. Realize that the atomic weights are based on the carbon twelve scale.
3. Define gram atomic weight and explain its meaning.
4. Describe the basic principles of the mass spectrometer.

*5. Calculate the average atomic weight of an element when given the masses and abundances of each component isotope. (Prob. 2.4)

*6. Calculate the percentage abundance of each isotope when given the average atomic weight of an element and the masses of each constitutent isotope. (Prob. 2.30)

.5 Masses of Atoms, Avogadro's Number

L Recognize that Avogadro's number is the number of atoms in one gram atomic weight of an element,

*2. Perform the following:

a. Calculate the mass of a sample when given the atomic weight of the element and the number of atoms. (Probs. 2.5a, 2.32b)
b. Calculate the number of atoms of an element when given the mass of the sample. (Probs. 2.5b, 2.32a)

.6 Masses of Molecules

1. Define molecular weight and explain its meaning.
2. Recognize that the gram molecular weiglit of a substance is the weight in grams which contains Avogadro's number of molecules.

*3. Perform the following:

a. Calculate the molecular weight when given the composition of a molecule. (Prob. 2.6a)
b. Calculate the mass of a sample of molecules when given the molecular weight and the number of molecules. (Prob. 2.33e)
c. Calculate the number of molecules when given the mass of a sample. (Prob. 2.6b)

ASSIGNMENT

Text: Chapter 2

Problems: Chapter 2, Numbers 2.1-2.5, 2.6a, b, 2.30, 2.32a, b, 2.33

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The Electronic Structure of Atorns

The goal of this unit is to develop a model of the electronic structure of atoms that is consistent with experimental evidence.

INSTRUCTIONAL OBJECTIVES

.1 Properties of Electrons in Atoms and Molecules

1. Summarize the postulates of the quantum theory.

.2 Experimental Basis of the Quantum Theory

1. Account for the origin of atomic spectra.

*2, Use Einstein's equation to calculate the energy change associated with the wavelength or frequency of a spectral line. (Probs. 6.1, 6.23)

*3. Use Equation 6.4 to calculate the wavelengths of Hnes in the hydrogen atomic spectrum. (Prob. 6.24)

.3 The Bohr Theory of the Hydrogen Atom

1. Recognize that Bohr's theory introduced the idea of quantized energy levels as indicated by Equation 6.5.

*2. Use Equation *6.5* and the Einstein equation to calculate the energy of transition or the wavelength associated with an electron transition in a hydrogen atom. (Prob. 6.2)

*3. Calculate the energy in a ground state or the ionization energy when given the charge on the nucleus and appropriate constants and energy conversion factors. (Prob- 6.26)

4. Summarize, qualitatively and in your own words, the Bohr model of the atom.

4 Waves and Particles .

1. Recognize the dual particle-wave nature of light and of electrons.
2. Summarize the implications of the de Broglie relation?
*3. Use Equation 6.10 to calculate the allowable energies of a particle confined to a region of a given length. (Prob. 6.28)
4. Interpret the wave function as the probability of finding an electron at a point in space, and as being proportional to the electron charge density at that point.

.5 Electron Arrangements in Atoms

*1. State the four quantum numbers that describe an electron, interpret the physical significance of these numbers, and apply the rules governing the assignment of them. (Probs. *6.5,* 6.36)
*2. Relate quantum numbers to s, p, d, f notations.
3. State the Pauli exclusion principle.
4. State Hund's rule.
*5. Write the electron configuration when given the atomic number of an element. (Probs. 6.3, 6.31, 6.32, 6.34)
*6. Draw an orbital diagram when given the atomic number or the electron configuration of an element. (Probs. 6.4, 6.33)
*7. Sketch the spatial arrangement of s and p atomic orbitals.

.6 Experimental Support for Electron Configurations

1. Define the term ionization energy.
2. Relate ionization energies to the electron configuration for a particular atom.

ASSIGMMENT

Text: Chapter 6

Problems: Numbers 6.1-6.5, 6.23, 6.24, 6.26, 6.2S, 6.31-6.34, 6.36

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Persodic Table

The goal of this unit is to associate periodic relationships and properties of the elements with electron configurations, and to classify and predict physical and chemical properties of pure substances based on these relationships.

INSTRUCTIONAL OBJECTIVES

.1 Structure of the Periodic Table

1. Recognize that elements are arranged in order of increasing atomic numbers in horizontal periods and vertical columns called groups.
2. Compare the number of elements in the various periods.
3. List some physical properties of the alkali metals.

*4. Predict the formulas and write equations for reactions between alkah metals and water, Group VI A, and Group VII A elements. (Prob. 7.20)

5. Recognize that the halogens exist as stable, diatomic molecules m the elementary' form.
6. List some physical properties of the halogens; recognize the trends in physical and chemical properties throughout the group.

*7. Predict the formulas and write equations for reactions between halogens and hydrogen, Group I A, and Group II A elements. (Prob. 7.20)

8. Recognize the unique properties of hydrogen.

.2 Correlation with Electron Configuration

*1. Relate group numbers to the number of electrons in the outermost principal energy levels. (Probs. 7.1, 7.25)

2. Compare the ph>'sical and chemical properties of transition metals (B subgroups) in periods 4, 5, and 6 to those of the alkali metals.
3. Recognize that tli^ simjlarity in properties of the lanthanides is related to the filhng of the 4f subleyels; in the actinides, to the filling of the 5f sublevels,

.3 Trends in Atomic Properties

1. Realize that, in general, atomic radii decrease from left to right across a period and increase from top to bottom within a group.
2. Recognize that the size of an atom is the result of a balance between electron-electron repulsions and electron-nucleus attractions.
3. Realize that, in general, ionization energies tend to increase from left to right across a period and decrease from top to bottom within a group, an inverse correlation with atomic radii.
4. Relate values for electronegativities to relative- tendencies to attract electrons.
5. Recognize that, in general, electronegativities increase from left to right across a period and decrease from top to bottom within a group, an inverse correlation with atomic radii.
6. List some physical properties of metals; associate metallic characteristics with low ionization energy.
7. List some physical properties of nonmetals; associate nonmetaiiic characteristics with a tendency to gain electrons.
8. List two unique properties of the noble gases; relate these properties to their electron configurations.
9. List some genera] physical and chemical properties of the metalloids.

4 Predictions Based on the Periodic Table

*1. Predict physical properties of elements when given corresponding properties of surrounding elements in the Periodic Table. (Prob. 7.2)

*2. Predict relative values of properties of elements such as electronegativity, ionization energy, atomic radius, metaUic character. (Probs. 7.3,7.24)

*3. Predict the fonnuias of binary and ternary compounds when given the formulas of analogous compounds formed by elements in the samiC groups of the Periodic Table. (Probs. 7.4, 7.29)

,5 Sources of the Elements

1. Correlate the position of an element in the Periodic Table with the source of the element.
2. Describe the chemical and physical processes involved in freeing elements from ore deposits.
3. Summarize the practices that may be used to conserve deposits of metallic ores.

ASSIGNMENT

Text: Chapter 7

Problems: Numbers 7.1-7.4, 7.20. 7.24-7.26, 7.29, 7.32

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Chemical Bondsmc

The goal of the unit is to consider the nature and properties of interatomic forces called chemical bonds.

INSTRUCTIONAL OBJECTIVES

.1 Ionic Bonding

1. Recognize that the transfer of electrons from atom.s of metals with low ionization energy to atoms of liighly electronegative non-metals produces ions.
2. Realize that the outer, incomplete energy levels are involved in .electron transfers and that, in many instances, the octet of a noble gas structure is produced as a result of the transfer.
3. Account for the fact that form.ation of an ionic solid from the elements is always an exothermic process by relating the sign and magnitude of the lattice energy to a hypothetical series of steps for the process.
4. Relate the charge on an ion to the electron configuration of the A group elements in the Periodic Table. (Prob. 8.1)
5. Recognize that the formation of cations from transition metals always involves the loss of outer s electrons. (Prob. S.30)
6. List the trends in sizes of monaromic ions and atoms in the Group A elements.
7. Learn the names and formulas of the polyatomic ions listed in Table 8.3.

*S. Apply the rules discussed in Section 8.1 to name ionic com-pounds. (Probs. 8.1. 8.28)

*9. Predict the fonnulas. name the com.pounds, and write balanced equations for the preparation *of* ionic compounds from the elements *whi:n* a Periodic Table is provided. (Prob. 3.29)

2 Nature of the Covalent Bond

1. Discuss the factors responsible for the energy minimum in covalent bond formation.
2. Recognize that according to the valence bond theory, a covalent bond consists of a pair of electrons of opposite spins filling an atomic orbital on both bonded atoms.

3 Properties of the Covalent Bond

1. Define the following terms: bond polarity, bond energy, bond length.
2. Predict relative bond polarities and the extent of ionic character based on differences in electronegativities. (Prob. 8.2)
3. Relate covalent bond lengths to atomic radii and the influence of the partial ionic character of the bond.
4. Realize that the bond energy is affected by the ionic character of the covalent bond.
5. Recognize that multiple bonds between the same two atoms result in increased bond strength and decreased bond length.

4 Lewis Structures; The Octet Rule

*1. Apply the appropriate rules to write Lewis structures for molecules and polyatomic ions. (Probs. 8.3, 8.38)
*2. Explain the concept of resonance; write reasonable structures for resonance forms. (Prob. 8.35)
3, State the octet rule and describe several exceptions to this rule.

,5 Molecular Geometry

*1. Predict bond angles and molecular geometry from Lewis structures based on electron pair repulsion principles. (Probs. 8.4, 8.38)
*2, Predict whether a molecule will be polar or nonpolar, knowing or having derived its geometry. (Probs. 8.5, 8.40)

6 Hybrid Atomic Orbitals

1. List the types of hybrid atomic orbitals discussed in Chapter 8 and characterize each as to the method of formation, number of orbiiais, and their orientation.
*2. Distinguish between sigma and pi bonds; identify sigma and pi bonds when given the formula of a molecule or polyatomic ion. (Prob. 8.43e)^
*3. Predict the types of hybrid bonds present in a molecule or polyatomic ion given the Lewis structure or the geometry of the species. (Probs. 8.6, 8.43)

7 Molecular Orbitals

1. Describe the three basic operations in the molecular orbital approach.
*2. Write a molecular orbital diagram for simple diatomic species; interpret the diagram in terms of the number and energy of bonds

ASSIGNMENT

Text: Chapter 8

Problems: Numbers 8.1-8.7, 8.28, 8.29, 8.30. 8.35, 8.38, 8.40. 8.43, 8.45

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The goal of this unit is to relate the physical properties of a pure substance to the nature of the structural units of the substance and the strength of the forces between these structural units.

INSTRUCTIONAL OBJECTIVES

1 Ionic Compounds

1. Recognize that the relatively high melting points of ionic compounds are due to strong electrostatic forces between ions.
2. Realize that ionic compounds in the molten state or in water solution are good electrical conductors.
3. Recognize that ionic compounds tend to be soluble in polar solvents such as water but msoluble in nonpolar solvents.

*4. Relate the melting points of ionic compounds to the charge densities of the ions (Probs. 9.1, 9.21)

*5. Recognize that certain kinds of ionic compounds decompose upon heating. (Prob. 9.25)

-2 Molecular Substances

1. List the general physical properties of molecular substances.
2. Distinguish between interatomic and intermoiecuiar forces in molecular substances.

*3. Relate trends in melting and boiling points of molecular substances to the molecular weights and polarity of these substances. (Probs. 9.2, 9.21)

4. Describe the origin *ot* intermoiecuiar forces and compare the relative strengths of these forces.

*5. Predict the types of intermoiecuiar forces that will operate in a variety of molecular substances. Correlate the physical properri;.-, of these substances with the types of forces. (Probs. 9.3, 9.23)

3 Macromolecular Substances

1. Recognize that a macromolecular substance is composed of a network of atoms held together by covalent bonds,
2. Relate the properties of macromolecular substances, such as aliotropic forms of carbon and the silicates, to their structure and bonding.

.4 Metals

1. List some properties that distinguish metals from other types of substances.
2. Interpret the properties of metals in terms of the electron-sea model.

ASSIGNMENT

Text: Chapter 9

Problems: Numbers 9.1-9.4, 9.18, 9.20, 9.21, 9.23, 9.25 9.2S

11.3 Nature of the Solid State

1. Relate the properties of a crystalline soUd to the arrangement, type, and nature of the attractive forces between particles in the crystal lattice.

*2. Use the Bragg equation to calculate the interparticle distance when given the angle and order of diffraction for x-rays of known wavelength. (Prob. 11.35)

*3. Compare the number of atoms and their locations in simple, body-centered, and face-centered cubic cells.

*4. Relate the cell dimensions to such quantities as atomic radius and density when given the type of unit cell. (Probs 11.3)

*5. Distinguish between n-type and p-type semiconductors.

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Complex ions: CoordSoation Cooipo3jnds

The goal of this unit is to consider the composition, geometry, and electronic structure of complex ions. Factors that relate to the stabihty and rate *oi* formation of complexes will also be considered.

INSTRUCTIONAL OBJECTIVES

Introduction

1. Define the terms complex ion, iigand, coordination number, central atom, and coordination compound.
2. Recognize that the formation of coordinate covalent bonds results from a reaction between a Lewis base and a Lewis acid.

. 1 Structures of Coordination Compounds; Charges of Complex Ions

*I. Relate the structure of a coordination compound to its conductivity in water solution. (Prob. 21.1)

*2. Determine the charge on a complex and on the central atom, given the formula of a coordination compound. (Probs. 21.1, 21.25b)

.2 Composition of Complex Ions

1. Relate the stability of a complex ion to the charge density of the metal ion and the base strength of the Iigand.
2. Realize that certain ligands can act as a chelating agent to form more than one bond with a metal ion.

*3. Determine the coordination number of the central atom in any complex, given the formula of the species.

.3 Geometry of Complex Ions

*1. Predict the geometry and draw a structural formula for a complex ion, given its structural formula. (Probs. 21.2, 21.30)

*-) Draw structural formulas to represent all the geometrical isomers of octahedral and square planar complexes, knowing the composition of the complex. (Probs. 21.2, 21.30)

3. Describe the structural difference between *cis* and *trans* isomers and methods of distinguishing between a *cis-trans* pair.

.4 Electronic Structure of Complex Ions

1. Describe the bonding in a complex ion using valence bond theory.
2. Review the concepts of hybridization and orbital diagrams (Chapter 8 in the text).

*3. Relate the coordination numbers 2, 4, and 6 to hybridizations of sp, sp^ or dsp-, and d^sp^ orbitals. (Probs. 21.3,21.33)

*4. Draw orbital diagrams that show the distribution of electrons around the central atom, given the formula and the geometry or having predicted the geometry. (Probs. 21.3, 21.33)

5, Relate magnetic properties of a species to the structure of the complex.

6. Summarize the essential features of the crystal-field theory.

*7. Using the crystal field approach, draw an orbital diagram for any octahedral complex, distinguishing between high spin and low spin complexes. (Prob. 21.4)

ASSIGNMENT

Text: Chapter 21

Problems: Numbers 21.1-21.4-, 21.25, 21.30, 21.33, 21.39, 21.41