Purdue University
Chemistry 11500 Testout Study Guide
Revised July 2017

This study guide describes the topics that should be mastered before you attempt the examination for credit in Chemistry 115. The material can be found in a number of books on the market. A list of possible textbooks is given below.

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IMPORTANT:

1. **YOU MAY ONLY TAKE THE TESTOUT EXAMINATION FOR A PARTICULAR CLASS ONCE.**
2. **YOU MAY ONLY USE AN APPROVED NON-PROGRAMMABLE CALCULATOR SUCH AS TI-30.**
3. Read this material thoroughly if you expect to take the test out examination.
4. Study the material listed in the outline.
5. Work as many practice problems as possible.
6. When you feel prepared to take the test-out exam, try the sample exam at the end of this study guide first.
7. Come to the examination rested and confident.

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The subject matter of a general chemistry course varies somewhat from institution to institution. Chemistry 11500 at Purdue University deals with chemical formulas, chemical equations, and the mole concept; chemical calculations including gram-mole and gram-gram calculations; the properties of gases and the kinetic molecular theory of gases; the properties of liquids and solids; semi-conductors; periodic chemistry; electrons in atoms and molecules; nuclear chemistry and reactions; bonding; Lewis structures and molecular geometry; and the energetics of chemical reactions; organic chemistry in terms of naming alkanes and four functional groups, you must be able to read and understand different representations of organic molecules. Many of these concepts are closely related. The mole concept is used extensively in studies of liquids, gases, and solids, while an understanding of electronic structure is essential for discussions of periodic chemistry, chemical bonding, and molecular geometry.

The topics presented in this outline should be studied before you attempt the sample exam at the end of this study guide. These topics are listed under headings according to those found in the text currently in use at Purdue. They may not appear in exactly this order in the textbook you study.

In preparing for the examination it is important to work as many problems as possible. The purpose of these problems must be understood, however. They should be used to measure your understanding of the concepts and principles involved, and not to test your ability to recall formulas or facts. Our examinations are designed to test whether you understand concepts rather than whether you remember formulas – in fact many of the formulas are given on a formula sheet. Knowledge of a limited number of equations, a clear understanding of what they mean and how they can be used, and an understanding of definitions of basic concepts should be sufficient to handle the vast majority of the problems encountered.

At the end of this study guide you will find a sample examination. Allow 90 minutes for the exam. The exam does not cover every point in the outline, since no examination can do that. However, if you have no difficulty with the sample exam, you should not have any difficulty with the examination for credit. The answers to the exam are given on the last page of this Study Guide. To help you estimate how well you are doing, note that 55% is considered passing.

Suggested Textbooks:

Chemistry & Chemical Reactivity, 9th ed by Kotz, Treichel & Townsend; Thomson/Brooks/Cole. ISBN-13: 978-1285462530.

Chemistry: The Molecular Nature of Matter and Change, 8th edition by Silberberg; McGraw-Hill. ISBN-13: 978-1259631757.

Chemistry, the Central Science by Brown, 13th edition by LeMay, Bursten & Murphy; Prentice-Hall. ISBN-13: 978-0321910417.

CHEMISTRY 11500 STUDY GUIDE

Students should be able to use the metric system, know how to measure mass, volume, and temperature, be able to convert between different units, use significant figures.

1. The mole, chemical formulas, and chemical equations.

   You should know the relationships between a mole of material and its weight, volume, concentration, or the number of atoms or molecules.

   You should be able to write the correct formula given the name of any "common" chemical compound; or given the formula, write the name.

   Given the formula for any compound you should be able to:

   (a) name the elements that make up the compound.
   (b) indicate the number of each kind of atom represented.
   (c) determine the mass of each element in one mole of compound.
   (d) calculate the molecular weight.

   Given the weight of a sample and the formula of the compound, you should be able to calculate:

   (a) the number of moles of the compound in the sample.
   (b) the number of moles of any one element in the sample.
   (c) the number of molecules in the sample.
   (d) the number of atoms of any one element in the sample.

2. Chemical stoichiometry

   Given all reactants and products for a chemical reaction, and any one of the following pieces of information, you should be able to calculate any other piece of information on the list.

   (a) the number of moles of one of the products or reactants.
   (b) the mass of any product or reactant.
   (c) the number of molecules of any product or reactant.
   (d) the number of atoms or mass of any single element involved.
   (e) the concentration and volume of a solution of reactant or product.

   Given the weight of two or more reactants or products in a chemical reaction you should be able to identify the limiting reagent, calculate the weight of any reactant consumed in the reaction, calculate the weight of any product produced in the reaction, and determine the weight of the excess reactant left over when the reaction has reached completion.

   Calculate and use percent yield.

3. Properties of gases.

Given any three of the following pieces of information, you should be able to calculate the fourth, assuming that the gas is ideal.

(a) the number of moles of gas, or the weight of the gas
(b) the pressure of the gas
(c) the volume of the gas
(d) the temperature of the gas

Given the volume of a gas at one temperature and pressure, you should be able to find the volume it would occupy at another temperature and pressure.

You should be able to determine the density of a gas from the pressure and temperature. You should be able to determine the molecular weight of a gas from its density.

From the equation for a reaction involving a gas, and the mass, moles or volume of a gaseous reactant, you should be able to find the mass, moles or volume of any other product or reactant.

4. Properties of liquids.

You should be able to use a microscopic or atomic/molecular scale model to describe the changes which occur when a solid becomes a liquid, or when a liquid becomes a gas. You should be able to explain the differences in the arrangements of the atoms or molecules, what happens to the average speed of the particles, what changes occur in the distance between particles, and the temperature changes that must occur.

You should know how to prepare a specified volume of a solution of known concentration, e.g., 200 mL of 0.100 M NaCl. You should be able to calculate the number of moles, the number of moles of ions produced, or the mass of solute dissolved in a given volume of solution of known concentration, e.g., how many grams of NaCl are present in 50.0 mL of a 1.50 M solution? You should be able to use a solution of known concentration to prepare a solution of a lower concentration by dilution, e.g., prepare 100 mL of 0.22 M HCl starting with a solution that is 2.50 M HCl.

Given the boiling point of a pure solvent, its molal boiling point elevation constant, and the molality of the solution, you should be able to calculate the boiling point of the solution. Conversely, you should be able to find the molality of a solution from the boiling point of that solution. You should be able to find the molecular weight of a solute from the molality of the solution, the boiling point of the solution, the boiling point of the pure solvent, and the molal boiling point elevation constant.

You should be able to calculate the freezing point of a solution from the freezing point of the pure solvent, its molal freezing point depression constant, and the molality of the solution. You should be able to find the molecular weight of a solute from the molality of the solution, the freezing point of the solution, the freezing point of the pure solvent, and the molal freezing point depression constant.

5. Properties of solids.

Identify the common cubic unit cells – cubic, face centered cubic, and body centered cubic, and know how many atoms are in each and where each is positioned.

You should be able to calculate any of the following quantities from some or all of the other measurements.

(a) unit cell edge
(b) locations of atoms
(c) interatomic distances
(d) density of the solid
(e) number of formula units per unit cell
(f) type of cubic crystal lattice
(g) coordinates of the atoms in the unit cell

6. Ions, naming, and periodic chemistry.

Identify the charge of main group monoatomic cations and anions based upon placement in the periodic table.

Identify the following ions based upon formula, correct charge, and or ball and stick image: chlorate, chlorite, cyanide, acetate, hydroxide, sulfate, sulfite, carbonate, nitrate, nitrite, phosphate, and phosphite.

Name and write formulas of ionic compounds of these ions such as $CaCl_2$ calcium chloride or $FeCl_3$, Iron (III) Chloride.

Name and write the formulas of molecular compounds.

Name and write formulas for the seven strong acids, carbonic acid, and acetic acid.

Name and write formulas for binary covalent (molecular) compounds.

Name simple alkanes up to six carbons. Read and identify organic molecules that are rendered as ball and stick models and skeleton diagrams.

Identify the following organic functional groups associated with the following classes of organic compounds in a molecule: alcohols, aldehydes, ketones, carboxylic acids, amines, esters, ethers, and amides.

Indicate whether a property such as, ionization energy, electronegativity, atomic weight, ionic radius, or atomic radius increases or decreases as we proceed down a column or across a row of the Periodic Table. Compare periodic properties among a group of elements or ions.

7. Electronic structure of atoms.

Given the symbol for an element or ion, and a Periodic Table, you should be able to determine the number of protons in the nucleus of that particle, and the number of electrons around the nucleus. Given the symbol for an isotope, you should be able to identify the numbers of protons, neutrons, and electrons (or vice versa).

From the position of the element in the Periodic Table you should be able to indicate the number of electrons in the outer or valence shell. Conversely, knowing the number of electrons in the valence shell, you should be able to identify the family or Group to which the elements belongs (thus, you should know the names of the families of elements in the periodic table).

You should be able to identify the orbitals that contain the valence electrons for any element in the Periodic Table. From the atomic number of an element or from a Periodic Table, you should be able to write the electronic configuration for any element, i.e., $ls^2\ 2s^2\ 2p^6$...etc.

8. Chemical bonding and related topics.

Given the symbol, name or atomic number for any element, you should be able to write the Lewis structure of that element. You should be able to write the Lewis or electron dot structure for any compound containing no more than three elements or if the connectivity of the atoms is given you should be able to complete it.

From the chemical and physical properties of a compound, e.g., the conductivity, melting point, heat of fusion, etc., you should be able to predict whether that compound is ionic or covalent.

Given a sample of an unknown compound, you should be able to describe a test that you could perform that would help you decide whether the compound is ionic or covalent.

You should be able to use a table of electronegativities to determine where the bond between two elements would best be described as ionic or covalent.

Using values for the radii of ions and/or the Periodic Table you should be able to predict which ionic compound will have the largest crystal lattice energy, e.g., which has the higher crystal lattice energy, Na_2O or MgO?

From the electron-dot or Lewis structure of a molecule you should be able to identify the distribution of bonding and non-bonding electron pairs. You should be able to predict the shape of the molecule including linear, trigonal planar, and tetrahedral and their derivatives (trigonal bipyramidal and octahedral are not included). Additionally, you should be able to identify if a molecule is polar.

If there are several acceptable Lewis structures for a given molecule, you should be able to write all possible resonance structures, and understand the implication of the existence of these resonance structures. Identify when a molecule or ion may have resonance structures.

You should be able to identify the atomic orbitals that are used to form bonds in covalent molecules. For example, when HF forms, what atomic orbitals overlap to form the bond? You should be able to draw diagrams that show how atomic orbitals overlap to form double and triple bonds, and you should be able to identify the atomic orbitals that form the sigma and pi bonds in these compounds.

You should understand what is meant by hybrid atomic orbitals and the shape of molecules that use sp, sp^2, or sp^3, hybrid orbitals, especially in organic molecules.

9. Chemical energetics.

You should be able to distinguish between exothermic and endothermic reactions, between reactions which lose heat and which gain heat from their surroundings, and reactions which should be identified by $\Delta H = -$ or $\Delta H = +$. You should be able to describe the conditions that are implied for solids, liquids, and gases when values of the standard state enthalpy, ÄH, are given.

Given an equation and the standard enthalpy of formation of each compound in the reaction, you should be able to calculate the change in the enthalpy for the reaction. (Note, this is only one of many different kinds of problems in which Hess' Law can be applied.) You should be able to set up reactions in the form of a series of small "steps" starting with the reactants and ending up with the products, and construct an enthalpy of reaction from these steps.

You should be able to use bond dissociation energies to estimate the enthalpy of reaction for reactions in which enthalpy of formation data are not available for all reactants and products.

10. Nuclear chemistry and reactions

Define radioactivity, nucleon, nuclide and isotope.

Describe the characteristics of radioactive emissions.

Use the concepts of radioactive decay and half-life to find the age of an object, decay constant half-life, or amount of material remaining.

11. Science Practices

The ideas of science and engineering cannot be engaged in and applied in the absence of inquiry and discourse that allow for the development and refinement of models and ideas. These are more than skills in the sense that they are applied knowledge that is specific to each practice below.

- Analyze and interpret data
- Use math and computational thinking
- Construct explanations (and evaluate them)
- Develop an argument from evidence (and evaluate them)

Sample Test for Chemistry 11500

1. This exam consists of 47 multiple choice questions.
2. For each question mark the one best answer.
3. Allow 90 minutes for this sample exam.
4. During the actual examination for credit, a list of the elements and their atomic weights will be provided. You should use such a list (not a Periodic Table) for this exam.
5. The answers may be found on the last page.

Questions 1-6 pertain to the following hydrocarbon combustion reaction:

$$C_7H_{16} + 11\ O_2 \rightarrow 7\ CO_2 + 8\ H_2O$$

_____1. What is the molar mass of C_7H_{16} ?

(a) 22.4 (b) 86.1 (c) 100.2 (d) 716 (e) 1102.2

Make sure of this answer since the next five depend on it!

_____2. How many moles of CO_2 will be produced by the combustion of 30 g of C_7H_{16} ?

(a) 210 (b) 21 (c) 2.1 (d) 0.3 (e) 3.3

_____3. If the prevailing temperature is 0^o C and the prevailing pressure 3 atmospheres, what volume of CO_2 can be produced from 10 g of C_7H_{16}?

(a) 0.7 L (b) 2.1 L (c) 15.7 L (d) 5.22 L (e) 47.1 L

_____4. The density of C_7H_{16} at 273^o C and 2 atmospheres pressure would be:

(a) 4.46 g/L (b) 8.92 g/L (c) 2.23 g/L (d) 1.12 g/L (e) 100 g/L

_____5. What weight of H_2O would be formed by the combustion of 20 g of C_7H_{16}?

(a) 3.6 g (b) 160 g (c) 144 g (d) 28.8 g (e) 62 g

_____6. 1 mole of C_7H_{16} and 11 moles of O_2 are caused to react in a closed container at such a temperature that all reactants and products are gases. The final pressure is:

(a) the same as the initial pressure.
(b) 5/4 times the initial pressure.
(c) 15 times the initial pressure.
(d) 15/11 times the initial pressure.
(e) 15/12 times the initial pressure.

_____7. If a single molecule of a substance weighs 5.34×10^{-23} g, the molecular weight must be:

(a) 28.1 (b) 32.14 (c) 56.2 (d) 64.28 (e) 128.56

_____8. The difference between $^{13}_{6}C$ and $^{12}_{6}C$ is:

(a) one electron.
(b) one proton.
(c) one electron and one proton.
(d) one neutron.
(e) not distinguishable.

_____9. A 1986 penny of mass 2.48 g is 6% copper by mass. How many copper atoms [AW Cu = 63.55] are contained in the penny?

(a) 2.34×10^{-3}

(b) 3.81

(c) 6.022×10^{23}

(d) 3.613×10^{22}

(e) 1.41×10^{21}

_____10. Ammonia (NH_3) reacts with O_2 as follows: $4\ NH_3 + 5\ O_2 \rightarrow 6\ H_2O + 4\ NO$
How many liters of O_2 (at STP) react with one mole of NH_3?

(a) 5 L

(b) 5 x 22.4 L

(c) 4 x 22.4 L

(d) $\frac{5 \times 22.4}{4}$ L

(e) $\frac{10 \times 22.4}{9}$ L

_____11. Hydrazoic acid, HN_3, decomposes qualitatively on heating as follows:

$$2\,HN_3 \rightarrow 3N_2 + H_2$$

If the initial pressure is 3 atm, what is the final pressure assuming the temperature and volume remain the same?

(a) 6 atm (b) 8 atm (c) 9 atm (d) 3 atm (e) 1.5 atm

_____12. Which of the following properties of an alcohol/water mixture is independent of temperature?

(a) density
(b) viscosity
(c) volume percent
(d) molarity
(e) mole fraction

_____13. Which of the following contains the largest number of carbon atoms?

(a) 0.25 moles carbon monoxide, CO
(b) 0.1 moles ethanol, C_2H_5OH
(c) 0.05 moles glucose, $C_6H_{12}O_6$
(d) 0.01 moles sucrose, $C_{12}H_{22}O_{11}$
(e) 0.01 moles diamond, C

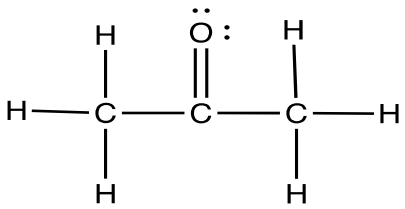
_____14. Which of the following are all ionic compounds?

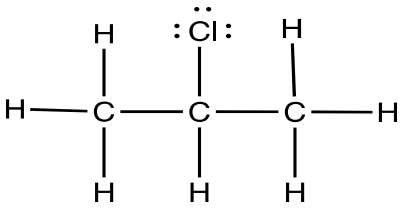
(a) LiCl, K_2O, NO_2.
(b) CO_2, Na_2SO_4, SCl_4
(c) SO_2, CO_2, PCl_5
(d) CsClO, KCl, Fe_2O_3

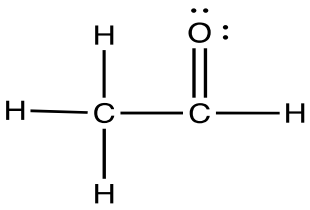
_____15. Which of the following is a polar molecule?

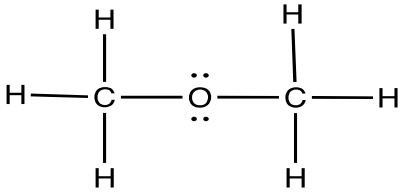
(a) CCl_4
(b) CO_2
(c) H_2O
(d) H_2Be

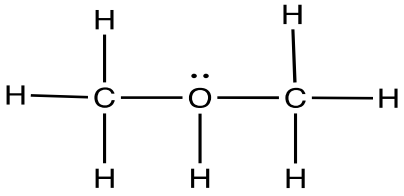
_____16. Which is not a valid Lewis Structure? (and you should know why)

A. 

B. 

C. 

D. 

E. 

_____17. What is the correct name for Na_2CO_3?

(a) Disodium carbon trioxide
(b) Disodium carbonate
(c) Sodium carbonate
(d) Sodium(I) carbonate

_____18. Name the following compound: H_3PO_4

(a) Trihydrogen phosphate.

(b) phosphoric acid

(c) phosphate acid

(d) trihydrogen phosphorous tetraoxide

(e) phosphorous acid

_____19. A light bulb apparatus to test conductivity shown below is used on four solutions in Beakers A through D. The results of placing the conductivity apparatus in each solution are summarized below

Beaker	Solution description	Conductivity test (light bulb)
A	Pure water	No light
B	Pure water and white solid	Light bulb glows brightly
C	Pure water and white solid	No light
D	Pure water and vinegar	Light bulb glows faintly

Which of these solutions contains a <u>non-electrolyte</u> and what experimental evidence supports your conclusion?

(a) Solution B because the light bulb glowed brightly indicating that the solid dissolved to produce many ions in the solution to complete the electric circuit.

(b) Solution C because the light bulb didn't glow indicating that the solid produced no ions when it dissolved in pure water.

(c) Solution D because the light bulb glowed faintly indicating that the solid dissolved to produce many ions in the solution to complete the electric circuit.

(d) All of the solutions contain a non-electrolyte because they all contain water.

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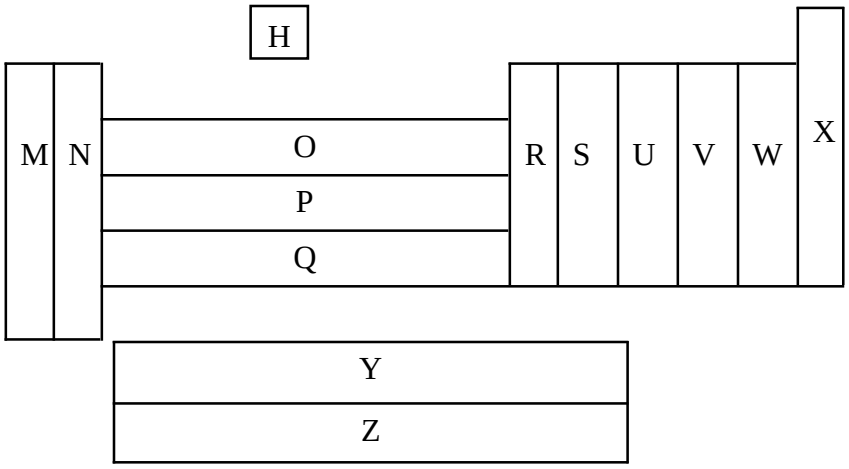
Use the following block outline of the Periodic Table to answer questions 20-24.



_____20. An element forms +2 ions compounds. Which block is it likely to be found in?

(a) M (b) N (c) 0 (d) V (e) X

_____21. An element, M, gives compounds with F, S, and O which have the formulas MF_4, MS_2 and MO^{-}_3. Which block will it fall in?

(a) N (b) Y (c) S (d) V (e) X

_____22. Hydrogen, by virtue of its unique structure and prototypic chemical and physical behavior, is best placed on its own in the Periodic Table. In the form of its +1 and – 1 ions (H^+ and H respectively) there is, however, some justification for associating H with block(s):

(a) M (b) X (c) M and N (d) M and W (e) M and X

_____23. The number of elements in block Y is:

(a) 6 (b) 8 (c) 10 (d) 14 (e) 18

_____24. The best insulators (non-conductors of both heat and electricity) will be found in block:

(a) M (b) 0 (c) X (d) Y (e) Z

_____25. Which of the following species is not planar?

(a) NO^{-}_3 (b) NH_3 (c) BCl_3 (d) SO_3

_____26. In which of the following pairs of chemical formulas do both members of the pair have the same number of atoms per molecule?

(a) HNO_3 and $Ca(OH)_2$

(b) $CoCl_2$ and $COCl_2$

(c) H_2SO_4 and H_2CO_3

(d) Each of these pairs have the same number of atoms per molecule.

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Use the following table to answer questions 27 to 30.

(a) $C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H = -393.5 kJ$
(b) $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(\ell)$	$\Delta H = -286$ kJ
(c) $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(\ell)$	$\Delta H = -890.4$ kJ
(d) $C(s) \rightarrow C(g)$	$\Delta H = +718.3$ kJ
(e) $H_2(g) \rightarrow 2\ H^o(g)$	$\Delta H = +435$ kJ

_____27. Which is the most exothermic of these reactions?

(a) (b) (c) (d) (e)

_____28. When 1 g of carbon is burned in oxygen:

(a) 393.5 kJ are evolved.
(b) 393.5 kJ are absorbed.
(c) 32.8 kJ are evolved.
(d) 32.8 kJ are absorbed.
(e) 4724.6 kJ are evolved.

_____29. Using the equations and the values given above, determine the ΔH (in kJ) for the following reaction, i.e., the standard heat of formation from its elements of CH_4:

$$C(s) + 2\ H_2(g) \longrightarrow CH_4(g) \quad H_f(CH_4) =$$

(a) +285.8 (b) – 285.8 (c) +75.1 (d) – 75.1 (e) none of these

_____30. The <u>average</u> bond energy of a C—H bond in CH_4 is:

(a) 236 kJ (b) 289 kJ (c) 331 kJ (d) 372 kJ (e) 414 kJ

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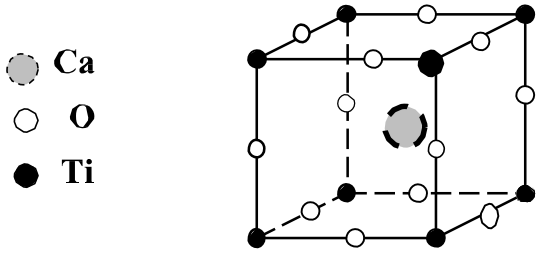
_____31. SO_2 can be represented by three different Lewis diagrams. What is the best term for this phenomenon?

(a) Isomers (b) Isotopes (c) epimers (d) resonance structures

The state mineral of Michigan, known as Perovskite, has an essentially cubic unit cell (of edges a_o) as shown in the diagram. [If Indiana has a state mineral it is probably limestone which is not cubic.] At each corner of the unit cell there is a titanium atom, at the center there is a calcium atom, and at the mid-point of each edge there is an oxygen atom. Now answer questions 32 and 33.



_____32. Take one of the twelve oxygen atoms at the center of an edge. Between how many unit cells is this atom shared?

(a) 2 (b) 4 (c) 6 (d) 8 (e) 12

_____33. The empirical (or simplest) formula is related to (in this case identical with) the number of atoms of each kind in the unit cell. The formula for Perovskite is thus:

(a) $CaTi_8O_{12}$

(b) $CaTiO_3$

(c) $CaTiO$

(d) $CaTi_2O_3$

(e) $CaTiO_2$

_____34. The radius of a cobalt atom is 125 pm. Calculate the edge length of the face-centered cubit unit cell of cobalt.

(a) 125 pm (b) 250 pm (c) 289 pm (d) 354 pm (e) 462 pm

_____35. Which of the following is <u>not</u> a member of the same iso-electronic series?

(a) $_{10}Ne$

(b) $_{9}F^{-}$

(c) $_{11}Na^{+}$

(d) $_{4}Be^{2+}$

(e) $_{7}N^{3-}$

_____36. Arrange the following ions in order of increasing size (smallest first):

S^{2-}, Mg^{2+}, Se^{2-}, Ca^{2+}

(a) $Mg^{2+} < S^{2-} < Ca^{2+} < Se^{2-}$

(b) $Mg^{2+} < Ca^{2+} < S^{2-} < Se^{2-}$

(c) $Mg^{2+} < S^{2-} < Se^{2-} < Ca^{2+}$

(d) $S^{2-} < Mg^{2+} < Se^{2-} < Ca^{2+}$

(e) $S^{2-} < Ca^{2+} < Mg^{2+} < Se^{2-}$

_____37. Which of the following compounds contain bonds with the <u>least</u> ionic character?

(a) KF

(b) BeF_2

© KCl

(d) $BeCl_2$

(e) BeS

_____38. Which of the following measurements represents the largest mass?

(a) 1.75×10^3 mg

(b) 3.8×10^6 μg

(c) 123 cg

(d) 0.10 g

(e) 5.89×10^{-4} kg

_____39. Which of the following transitions in a hydrogen atom results in the <u>absorption</u> of a photon of the largest energy?

$$\Delta E = R_H \left[\frac{1}{n^2} - \frac{1}{m^2} \right]$$

(a) n = 1 to m = 2

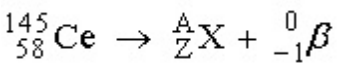
(b) n = 2 to m = 1

(c) n = 5 to m = 9

(d) n = 3 to m = 8

(e) n = 8 to m = 3

_____40. Identify the atomic number of *x*:



(a) 57
(b) 145
(c) 86
(d) 59
(e) 203

_____41. P-32, a radioisotope used in leukemia therapy, has a half-life of 14.26 days. What percent of a sample remains after 25 days?

(a) 3.37%
(b) 25%
(c) 30%
(d) 35%
(e) 50%

*****Additional help (problem solving by topic) is available here:**
http://www.chem.purdue.edu/gchelp/
This is a site with multiple questions on many different topics!

Chem 11500 Test-out Exam Study Guide

ANSWERS

1. C
2. C
3. D
4. A
5. D
6. E
7. B
8. D
9. E
10. D
11. A
12. E
13. C
14. D
15. C
16. E
17. C
18. B
19. B
20. B
21. C
22. D
23. D
24. C
25. B
26. A
27. C
28. C
29. D
30. A
31. D
32. B
33. B
34. D
35. D
36. B
37. E
38. B
39. A
40. D
41. C