Dougherty Valley • AP Chemistry

AP Test Review

Name_______________________________

Period ________ Date ____________

B I G I D E A 1 : A T O M S

1 – Review the Content

- Honors Chemistry: Lessons 4.1, 4.2, 5.4, 5.5; Units 2, 9
- AP Chemistry: Lessons 1.1, 1.2, 1,3; Unit 8
- Textbook: Ch 2, 4, 7, 8, 9, 10
- D&S Review: Ch 1, 5, and 6
- 5 Steps to a 5: Ch 5, 10, 13, Ch 19, #1-4
- Princeton Review: Ch 3
- Crash Course: Ch 2-6

2 – Review the Essential Knowledge and Learning Objectives

Read through and annotate the Essential Knowledge and Learning Objectives for this Big Idea. Then make a list of the ideas and topics here.

3 – Multiple Choice Review

List items that you missed. Make notes for why you missed them and what you learn from it.

Packet Q# Reason for Mistake Takeaways

4 – Free Response Practice

Reflect on your responses for FR questions. Make notes about how to craft stronger responses.

South Pasadena • AP Chemistry

Name______________________________

AP Test Review

Period ________ Date ____________

BIG IDEA 1: ATOMS

Essential Knowledge

1. **The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.**
The atomic theory of matter is the most fundamental premise of chemistry. A limited number of chemical elements exist, and the fundamental unit of the chemical identities they carry is the atom. Although atoms represent the foundational level of chemistry, observations of chemical properties are always made on collections of atoms, and macroscopic systems involve such large numbers that they are typically counted in the unit known as the mole rather than as individual atoms. For elements, many chemical and physical properties exhibit predictable periodicity as a function of atomic number. In all chemical and physical changes, atoms are conserved.

1.A. All matter is made of atoms. There are a limited number of types of atoms; these are the elements.
The concept of atoms as the building blocks of all matter is a fundamental premise of the discipline of chemistry. This concept provides the foundation for conceptualizing, interpreting, and explaining the macroscopic properties and transformations observed inside and outside the laboratory in terms of the structure and properties of the constituent materials. The concept of the mole enables chemists to relate measured masses in the laboratory to the number of particles present in a sample. These two concepts also provide the basis for the experimental determination of the purity of a sample through chemical analysis. The most important aspect of chemistry is not the memorization of the laws and definitions, but rather the ability to explain how the laws and relationships arise because of the atomic nature of matter.

1.A.1. Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions.

a. The average mass of any large number of atoms of a given element is always the same for a given element.
b. A pure sample contains particles (or units) of one specific atom or molecule; a mixture contains particles (or units) of more than one specific atom or molecule.
c. Because the molecules of a particular compound are always composed of the identical combination of atoms in a specific ratio, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.
d. Pairs of elements that form more than one type of molecule are nonetheless limited by their atomic nature to combine in whole number ratios. This discrete nature can be confirmed by calculating the difference in mass percent ratios between such types of molecules.

1.A.2. Chemical analysis provides a method for determining the relative number of atoms in a substance, which can be used to identify the substance or determine its purity.

a. Because compounds are composed of atoms with known masses, there is a correspondence between the mass percent of the elements in a compound and the relative number of atoms of each element.
b. An empirical formula is the lowest whole number ratio of atoms in a compound. Two molecules of the same elements with identical mass percent of their constituent atoms will have identical empirical formulas.
c. Because pure compounds have a specific mass percent of each element, experimental measurements of mass percents can be used to verify the purity of compounds.

1.A.3. The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.

a. Atoms and molecules interact with one another on the atomic level. Balanced chemical equations give the number of particles that react and the number of particles produced. Because of this, expressing the amount of a substance in terms of the number of particles, or moles of particles, is essential to understanding chemical processes.

b. Expressing the mass of an individual atom or molecule in atomic mass unit (amu) is useful because the average mass in amu of one particle (atom or molecule) of a substance will always be numerically equal to the molar mass of that substance in grams.

c. Avogadro’s number provides the connection between the number of moles in a pure sample of a substance and the number of constituent particles (or units) of that substance.

d. Thus, for any sample of a pure substance, there is a specific numerical relationship between the molar mass of the substance, the mass of the sample, and the number of particles (or units) present.

1.B. The atoms of each element have unique structures arising from interactions between electrons and nuclei.

The shell model arises from experimental data. The shell model forms a basis for understanding the relative energies of electrons in an atom. The model is based on Coulomb’s Law and qualitatively predicts ionization energies, which can be measured in the lab. Understanding how the shell model is consistent with the experimental data is a key learning goal for this content, beyond simple memorization of the patterns of electron configurations.

1.B.1. The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb’s Law is qualitatively useful for understanding the structure of the atom.

a. Based on Coulomb’s Law, the force between two charged particles is proportional to the magnitude of each of the two charges (q_1 and q_2), and inversely proportional to the square of the distance, r, between them. (Potential energy is proportional to q_1q_2/r.) If the two charges are of opposite sign, the force between them is attractive; if they are of the same sign, the force is repulsive.

b. The first ionization energy is the minimum energy needed to remove the least tightly held electron from an atom or ion. In general, the ionization energy of any electron in an atom or ion is the minimum energy needed to remove that electron from the atom or ion.

c. The relative magnitude of the ionization energy can be estimated through qualitative application of Coulomb’s Law. The farther an electron is from the nucleus, the lower its ionization energy. When comparing two species with the same arrangement of electrons, the higher the nuclear charge, the higher the ionization energy of an electron in a given subshell.

d. Photoelectron spectroscopy (PES) provides a useful means to engage students in the use of quantum mechanics to interpret spectroscopic data and extract information on atomic structure from such data. In particular, low-resolution PES of atoms provides direct evidence for the shell model. Light consists of photons, each of which has energy $E = h\nu$, where h is Planck’s constant and ν is the frequency of the light. In the photoelectric effect, incident light ejects electrons from a material. This requires the photon to have sufficient energy to eject the electron. Photoelectron spectroscopy determines the energy needed to eject electrons from the material. Measurement of these energies provides a method to deduce the shell structure of an atom. The intensity of the photoelectron signal at a given energy is a measure of the number of electrons in that energy level.

e. The electronic structure of atoms with multiple electrons can be inferred from evidence provided by PES. For instance, both electrons in He are identical, and they are both roughly the same distance from the nucleus as in H, while there are two shells of electrons in Li, and the outermost electron is further from the nucleus than in H.

1.B.2. The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells; the energetics of the electrons in the atom can be understood by consideration of Coulomb's Law.

a. Electron configurations provide a method for describing the distribution of electrons in an atom or ion.
b. Each electron in an atom has a different ionization energy, which can be qualitatively explained through Coulomb's Law.
c. In multi-electron atoms and ions, the electrons can be thought of as being in "shells" and "subshells," as indicated by the relatively close ionization energies associated with some groups of electrons. Inner electrons are called core electrons, and outer electrons are called valence electrons.
d. Core electrons are generally closer to the nucleus than valence electrons, and they are considered to "shield" the valence electrons from the full electrostatic attraction of the nucleus. This phenomenon can be used in conjunction with Coulomb's Law to explain/rationalize/predict relative ionization energies. Differences in electron-electron repulsion are responsible for the differences in energy between electrons in different orbitals in the same shell.

1.C. Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle for understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.

Although a simple shell model is not the currently accepted best model of atomic structure, it is an extremely useful model that can be used qualitatively to explain and/ or predict many atomic properties and trends in atomic properties. In particular, the arrangement of electrons into shells and subshells is reflected in the structure of the periodic table and in the periodicity of many atomic properties. Many of these trends in atomic properties are important for understanding the properties of molecules, and in being able to explain how the structure of the constituent molecules or atoms relates to the macroscopic properties of materials. Students should be aware that the shells reflect the quantization inherent in quantum mechanics and that the labels given to the atomic orbitals are examples of the quantum numbers used to label the resulting quantized states. Being aware of the quantum mechanical model as the currently accepted best model for the atom is important for scientific literacy.

1.C.1. Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.

a. The structure of the periodic table is a consequence of the pattern of electron configurations and the presence of shells (and subshells) of electrons in atoms.
b. Ignoring the few exceptions, the electron configuration for an atom can be deduced from the element's position in the periodic table.
c. For many atomic properties, trends within the periodic table (and relative values for different atoms and ions) can be qualitatively understood and explained using Coulomb's Law, the shell model, and the concept of shielding/effective nuclear charge. These properties include:
   1. First ionization energy
   2. Atomic and ionic radii
   3. Electronegativity
   4. Typical ionic charges

d. Periodicity is a useful tool when designing new molecules or materials, since replacing an element of one group with another of the same group may lead to a new substance with similar properties. For instance, since SiO_2 can be a ceramic, SnO_2 may be as well.

1.C.2. The currently accepted best model of the atom is based on the quantum mechanical model.

a. Coulomb's Law is the basis for describing the energy of interaction between protons and electrons.
b. Electrons are not considered to follow specific orbits. Chemists refer to the region of space in which an electron is found as an orbital.
c. Electrons in atoms have an intrinsic property known as spin that can result in atoms having a magnetic moment. There can be at most two electrons in any orbital, and these electrons must have opposite spin.
d. The quantum mechanical (QM) model addresses known problems with the classical shell model and is also consistent with atomic electronic structures that correspond with the periodic table.
e. The QM model can be approximately solved using computers and serves as the basis for software that calculates the structure and reactivity of molecules.

1.D. Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.

Because the experimental measurement of ionization energy provides a window into the overall electronic structure of the atom, this content provides rich opportunities to explore how scientific models can be constructed and refined in response to available data. The modern use of mass spectrometry provides another example of how experimental data can be used to test or reject a scientific model.

1.D.1. As is the case with all scientific models, any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data.

a. Scientists use experimental results to test scientific models. When experimental results are not consistent with the predictions of a scientific model, the model must be revised or replaced with a new model that is able to predict/explain the new experimental results. A robust scientific model is one that can be used to explain/ predict numerous results over a wide range of experimental circumstances.
b. The construction of a shell model of the atom through ionization energy information provides an opportunity to show how a model can be refined and changed as additional information is considered.

1.D.2. An early model of the atom stated that all atoms of an element are identical. Mass spectrometry data demonstrate evidence that contradicts this early model.

a. Data from mass spectrometry demonstrate evidence that an early model of the atom (Dalton's model) is incorrect; these data then require a modification of that model.
b. Data from mass spectrometry also demonstrate direct evidence of different isotopes from the same element.
c. The average atomic mass can be estimated from mass spectra.

1.D.3. The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration.

a. The energy of a photon is related to the frequency of the electromagnetic wave through Planck's equation ($E = h\nu$). When a photon is absorbed (or emitted) by a molecule, the energy of the molecule is increased (or decreased) by an amount equal to the energy of the photon.
b. Different types of molecular motion lead to absorption or emission of photons in different spectral regions. Infrared radiation is associated with transitions in molecular vibrations and so can be used to detect the presence of different types of bonds. Ultraviolet/visible radiation is associated with transitions in electronic energy levels and so can be used to probe electronic structure.

c. The amount of light absorbed by a solution can be used to determine the concentration of the absorbing molecules in that solution, via the Beer-Lambert Law.

1.E. Atoms are conserved in physical and chemical processes.

The conservation of mass in chemical and physical transformations is a fundamental concept, and is a reflection of the atomic model of matter. This concept plays a key role in much of chemistry, in both quantitative determinations of quantities of materials involved in chemical systems and transformations, and in the conceptualization and representation of those systems and transformations.

1.E.1. Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.

a. Various types of representations can be used to show that matter is conserved during chemical and physical processes.
    1. Symbolic representations
    2. Particulate drawings

b. Because atoms must be conserved during a chemical process, it is possible to calculate product masses given known reactant masses, or to calculate reactant masses given product masses.

c. The concept of conservation of atoms plays an important role in the interpretation and analysis of many chemical processes on the macroscopic scale. Conservation of atoms should be related to how nonradioactive atoms are neither lost nor gained as they cycle among land, water, atmosphere, and living organisms.

1.E.2. Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants, as well as the efficiency of the transformation.

a. The number of atoms, molecules, or formula units in a given mass of substance can be calculated.

b. The subscripts in a chemical formula represent the number of atoms of each type in a molecule.

c. The coefficients in a balanced chemical equation represent the relative numbers of particles that are consumed and created when the process occurs.

d. The concept of conservation of atoms plays an important role in the interpretation and analysis of many chemical processes on the macroscopic scale.

e. In gravimetric analysis, a substance is added to a solution that reacts specifically with a dissolved analyte (the chemical species that is the target of the analysis) to form a solid. The mass of solid formed can be used to infer the concentration of the analyte in the initial sample.

f. Titrations may be used to determine the concentration of an analyte in a solution. The titrant has a known concentration of a species that reacts specifically with the analyte. The equivalence of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the end point of the titration.

Learning Objectives

1.1 The student can justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory. EK 1.A.1

1.2 The student is able to select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures. EK 1.A.2

1.3 The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance. EK 1.A.2

1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively. EK 1.A.3

1.5 The student is able to explain the distribution of electrons in an atom or ion based upon data. EK 1.B.1

1.6 The student is able to analyze data relating to electron energies for patterns and relationships. EK 1.B.1

1.7 The student is able to describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb's Law to construct explanations of how the energies of electrons within shells in atoms vary. EK 1.B.2

1.8 The student is able to explain the distribution of electrons using Coulomb's Law to analyze measured energies. EK 1.B.2

1.9 The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model. EK 1.C.1

1.10 Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity. EK 1.C.1

1.11 The student can analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data are not supplied. EK 1.C.1

1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model. EK 1.C.2

1.13 Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence. EK 1.D.1

1.14 The student is able to use data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element. EK 1.D.2

1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules. EK 1.D.3

1.16 The student can design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution. EK 1.D.3

1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. EK 1.E.1

1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes. EK 1.E.2

1.19 The student can design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. EK 1.E.2

1.20 The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. EK 1.E.2

South Pasadena • AP Chemistry

AP Test Review

Name_____________________________

Period ________ Date ____________

FREE RESPONSE PRACTICE

Abide by the time guidelines. Use only (1) a black or blue pen or No. 2 pencil, (2) a scientific or graphing calculator, and (3) the provided Periodic Table and list of Equations and Constants.

Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved at arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored.

2014 AP Chemistry #1 (23 minutes)

Mass of KI tablet	0.425 g
Mass of thoroughly dried filter paper	1.462 g
Mass of filter paper + precipitate after first drying	1.775 g
Mass of filter paper + precipitate after second drying	1.699 g
Mass of filter paper + precipitate after third drying	1.698 g

A student is given the task of determining the I^- content of tablets that contain KI and an inert, water-soluble sugar as a filler. A tablet is dissolved in 50.0 mL of distilled water, and an excess of 0.20 *M* $Pb(NO_3)_2(aq)$ is added to the solution. A yellow precipitate forms, which is then filtered, washed, and dried. The data from the experiment are shown in the table above.

(a) For the chemical reaction that occurs when the precipitate forms,

(i) write a balanced, net-ionic equation for the reaction, and

(ii) explain why the reaction is best represented by a net-ionic equation.

(b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.

(c) In the filtrate solution, is $[K^+]$ greater than, less than, or equal to $[NO_3^-]$? Justify your answer.

(d) Calculate the number of moles of precipitate that is produced in the experiment.

(e) Calculate the mass percent of I^- in the tablet.

(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of I^- will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.

(g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 *M* $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}.

(i) Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

GO ON TO THE NEXT PAGE.

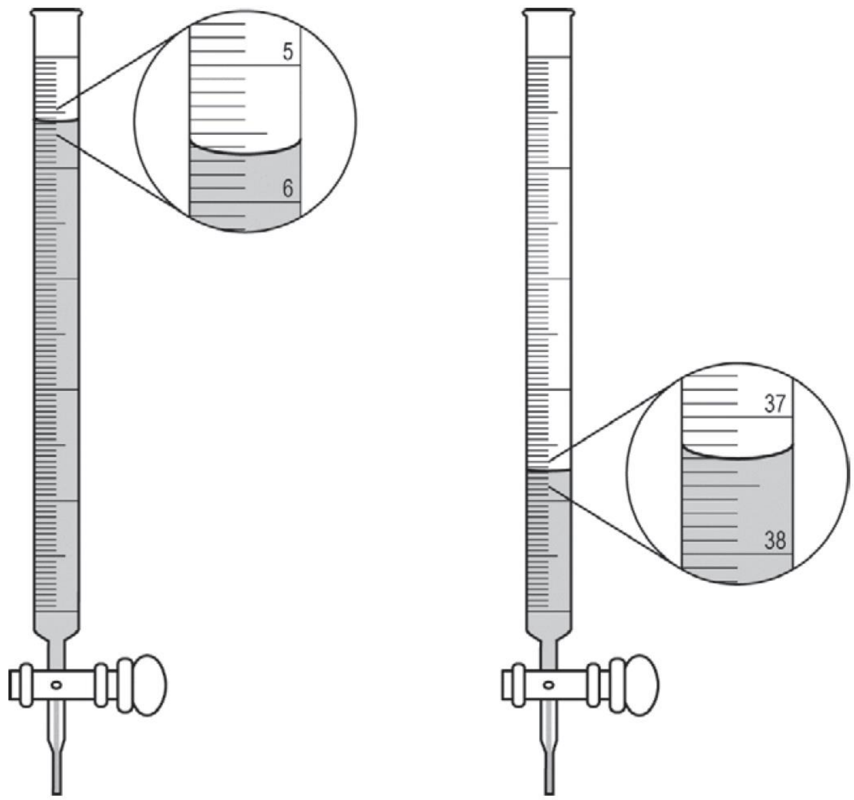
ADDITIONAL PAGE FOR ANSWERING QUESTION #1

GO ON TO THE NEXT PAGE.

2016 AP Chemistry #7 (9 minutes)

A student is given a 25.0 mL sample of a solution of an unknown monoprotic acid and asked to determine the concentration of an acid by titration. The student uses a standardized solution of 0.110 *M* NaOH(*aq*), a buret, a flask, an appropriate indicator, and other equipment necessary for the titration.

(a) The images below show the buret before the titration begins (below left) and at the end point (below right). What should the student record as the volume of NaOH(*aq*) delivered to the flask?



(b) Based on the given information and your answer to part (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

(c) In a second trial, the student accidentally added more NaOH(*aq*) to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION #7

GO ON TO THE NEXT PAGE.