Objective 11a: Light and atomic structure: apply quantum numbers to write electron configuration of atoms, identify valence electrons, draw Lewis dot symbols.

Quiz Practice problems

Key ideas:

Particle-wave duality. A wave can behave like a particle (photoelectric effect); a particle can behave like a wave (electron diffraction). deBroglie equation: $\lambda = h/mv$

The idea that a particle can behave like a wave led to Quantum Theory of the atom – treat electrons like a wave (the math equation is called a wave function) – involves the probability of finding an electron in a specific region of space and the uncertainty principle.

A wave function for an electron in an atom is called an atomic orbital. Information (energy, location, etc.) about an electron in an atom is described with the four quantum numbers.

Skills: relate wavelength, mass, and velocity of a particle using deBroglie equation.

Understand meaning of each quantum number.

Relate atomic orbital, e.g., 1s, to the four quantum numbers.

Draw energy level diagram of atomic orbitals.

Write electron configuration for 1^{st} 20 elements in periodic table.

Identify valence electrons.

Draw Lewis dot symbols for 1^{st} 20 elements.

1. In 2004, researchers at Oak Ridge National Laboratory and Nion Company reported that they produced the highest resolution electron microscope in the world with an actual resolution limit of 0.6 Angstroms (Chemical and Engineering News, 9/20/04, p. 13).

a. Compare a light microscope to an electron microscope. What property of light is used in a light microscope? What property of an electron is used in an electron microscope?

b. What is the wavelength of an electron to give a resolution of 0.6 Angstroms? Note: resolution = 0.5 (observation wavelength)

c. Calculate the speed of an electron that corresponds to this wavelength. (Which equation should you use? Answer: speed is approximately 6E6 m/sec = 6×10^6 m/sec)

2. Quantum theory uses a wave function to describe how a particle behaves like a wave. The wave function of an electron in an atom is called an atomic orbital. An electron in an atom is described with four quantum numbers.

You've seen the atomic orbitals (AO) 1s 2s, 2p, 3s, and 3p.

a. The 1 in 1s, 2 in 2s and 2p, and 3 in 3s and 3p refer to the principal quantum number (symbol = n) and tell use the relative energy of an electron.

Compare the 1s and 2s AO. As n increases, what happens to the energy?

b. The s in 1s and 2s and p in 2p and 3p refer to the angular momentum quantum number (symbol = ℓ). The ℓ quantum number tells us the shape of an AO, which tells us the probability of finding an electron in the region of space as described by the AO shape.

You know the shape of a s AO is spherical. Is the probability of finding an electron outside of the spherical region high or low?

c. You know there is only one type of s AO and three types of p AO's. This refers to the orientation in space of the AO. A s AO has only one orientation (only one orientation for a sphere). The p AO's have three orientations in space (p_x, p_y, and p_z). The magnetic quantum number (symbol = m_ℓ) tells us about this orientation in space. This m_ℓ quantum number depends on the ℓ quantum number.

For a s AO, $\ell = 0$ and $m_\ell = 0$. Only one value for m_ℓ, so only one orientation in space.

For a p AO, $\ell = 1$ and $m_\ell = 0, 1,$ and -1. Three values for m_ℓ, so three orientations in space.

(iii) For a d AO, ℓ = _____ and m_ℓ = ______. _____ values for m_ℓ, so _____ orientations in space.

3. a. In the structure of an atom, where is almost all of the <u>mass</u> of an atom? What occupies almost all of the <u>volume</u> of an atom?

b. The electron configuration of an atom tells us how electrons are distributed around the nucleus of an atom.

For example, nitrogen has 7 electrons and an electron configuration of $1s^2$, $2s^2$, $2p^3$.

You can either look up the electron configuration of an atom or apply the building up principle, Hund's rule, and the Pauli exclusion principle. We want to know about the valence electrons because these are the electrons that are responsible for bonding atoms to form compounds.

(i) How many valence electrons does nitrogen have? (Hint: see Group number in Periodic Table.)

(ii) See the electron configuration of carbon. Which electrons are the valence electrons? (Answer: $2s^2$, $2p^3$)

c. Draw the Lewis dot symbol of nitrogen. (Answer: ·Ṅ· ·· Note the 3 unpaired electrons and lone pair of electrons match the valence electron configuration of nitrogen.)
d. Atoms are very stable (low energy) when their electron shell is completely filled with 8 electrons. How many electrons does nitrogen need to have a completely filled shell? (Answer: either gain 3 electrons or lose 5 electrons.)

e. Fill in the blanks in the table.

element	electron configuration	Group #	valence electrons	Lewis dot symbol	electrons gained or lost for completely filled shell
Na	$1s^2\ 2s^2\ 2p^6\ 3s^1$				
Cl	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$				
Ca					
O					

4. Reactivity of Metals has to do with ionization energy and the distance an electron is from the nucleus of an atom. You place a piece of Mg metal in a beaker filled with water. You place a piece of Ca metal in a second beaker filled with water.
a. Which reaction occurs faster? In other words, which metal is more reactive? Give reasons.
b. For the reaction that occurs faster, write a molecular equation and net ionic equation.
c. Calculate ΔH of reaction for the reaction in part b. (Use your net ionic equation.)
d. If 2.5 g of the metal that reacts faster is added to 1 cup (240 ml) of water, calculate the final temperature of the water. Assume T_i of water = 25°C.

Objective 11b: Draw Lewis structures, distinguish isomers
Quiz Practice problems
Key ideas:
Valence electrons are the electrons involved in bonding atoms together to form compounds.
# of valence electrons = Group #
General bonding rules for neutral molecules: C = 4 bonds, N = 3 bonds + 1 lone pair (l.p.), O = 2 bonds and 2 l.p., X (F, Cl, Br, I) = 1 bond and 3 l.p., H = 1 bond and 0 l.p.
For the following compounds,
(i) Draw the Lewis dot symbol of each atom.
(ii) Determine total number of valence electrons in the molecule.
(iii) Draw the Lewis structure of the molecule.
(iv) Identify and distinguish between isomers.
Isomers are two or more compounds that have the same chemical formula but different ways the atoms are connected (bonded) in a molecule.

Skills: Draw Lewis structure of molecules.
Draw Lewis structures of isomers of a compound.

1. The molecules below have single bonds:
a. Ammonia (you've smelled it) = NH_3. (Answer: 8 total valence electrons. N (3.0) is more electronegative than H (2.2). The N-H bond is a polar bond.)

b. Natural gas (fuel used in stoves) = CH_4
Methanol (common organic solvent) = CH_3OH (Answer: 14 total valence electrons. C-O and C-H bonds are polar.)
Ethanol (common organic solvent, used in fuels) = CH_3CH_2OH or C_2H_6O.
Dimethyl ether (common organic solvent) = C_2H_6O. Dimethyl ether has the same chemical formula as ethanol but the way the atoms are bonded together is different. Two compounds that have the same chemical formula but different bonding are called **isomers**.

2. These compounds have at least one double bond.
Oxygen (we need this to survive) = O_2
Carbon dioxide (product of combustion reaction, global warming gas) = CO_2 (Answer: 16 total valence electrons.)
Ethylene (fuel, used to make many different organic compounds) = C_2H_4
Formic acid (the substance that ants emit when they bite you that causes the bite wound to sting) = HCOOH
Benzene (common organic solvent, carcinogen) = C_6H_6 (this compound is a six sided ring)

3. These compounds have at least one triple bond.
Nitrogen (air is 80% of this gas) = N_2
Carbon monoxide (side product of combustion, toxic) = CO
Acetylene (fuel, used in torches) = C_2H_2

4. Bigger molecules have more atoms. More atoms means there can be different ways the atoms can bond together. Two or more compounds that have the same chemical formula but different connectivity (different ways the atoms are bonded to each other) are called isomers.
a. butane (used in camping stoves) = C_4H_{10}. There are two isomers. Draw the Lewis structures of each isomer.
b. hexane (component of gasonline) = C_6H_{14}. There are several isomers. Draw the Lewis structures of two isomers.