Section 12: Lewis Structures

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Science TAC §112.35(c).

12.01 Electronegativity
- Chemistry (5)(C)

12.02 Electron Dot Symbols
- Chemistry (6)(E)

12.03 Electron Dot Formulas in Ionic Compounds
- Chemistry (7)(C)

12.04 Electron Dot Formulas in Covalent Compounds
- Chemistry (7)(C)

12.05 Resonance Structures
- Chemistry (7)(C)

12.06 VSEPR Molecular Geometry/Shape
- Chemistry (7)(E)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.

Safety Note: Any chemicals mentioned in these videos are potentially harmful and should be handled with the appropriate safety precautions.

12.01

Electronegativity

Electronegativity is the ability of neutral atoms to attract electrons when the neutral atom is in a compound. Electronegativity is a property of elements that can be used to predict the types of bonds that will form during a reaction.

Electronegativity values are expressed in Pauling units, named after Linus Pauling, who was the first person to define electronegativity.

The values for electronegativity increase from bottom to top within a group in the periodic table. For representative elements, the values usually increase from left to right across a period in the periodic table. The noble gases are omitted because they do not form many compounds.

Electronegativity Values for Selected Elements						
H 2.20						
Li 0.98	**Be** 1.57	**B** 2.04	**C** 2.55	**N** 3.04	**O** 3.44	**F** 3.98
Na 0.93	**Mg** 1.31	**Al** 1.61	**Si** 1.90	**P** 2.19	**S** 2.58	**Cl** 3.16
K 0.82	**Ca** 1.00	**Ga** 1.81	**Ge** 2.01	**As** 2.18	**Se** 2.55	**Br** 2.96
Rb 0.82	**Sr** 0.95	**In** 1.78	**Sn** 1.96	**Sb** 2.05	**Te** 2.10	**I** 2.66
Cs 0.79	**Ba** 0.89	**Tl** 1.62	**Pb** 2.33	**Bi** 2.02		

1. Arrange nitrogen, potassium, silicon, and sodium in order of increasing electronegativity.

   A. N, Na, Si, K
   B. K, Na, Si, N
   C. K, Si, Na, N
   D. N, Si, Na, K

12.02

Electron Dot Symbols

Electron dot symbols show how valence electrons are arranged using single dots on the sides of an atomic symbol (for one to four valence electrons) or with one or more pairs of dots on the sides of an atomic symbol (for five to eight valence electrons).

Chemical reactions mainly occur among the ***valence electrons*** of atoms because the valence electrons are the outermost electrons in an element. For representative elements, the number of valence electrons an atom has matches the group number in the 1A–8A groups. For example, nitrogen belongs to group 5A, so it has five valence electrons.

1. Determine the number of valence electrons in ammonium carbonate, $(NH_4)_2CO_3$.

   A. 48
   B. 35
   C. 32
   D. 40

12.03

Electron Dot Formulas in Ionic Compounds

An ***ionic compound*** is a compound composed of cations and anions.

- When an atom loses one or more valence electrons, a positively charged ion is produced, also known as a ***cation***.
- When an atom gains one or more valence electrons, a negatively charged ion is produced, also known as an ***anion***.

Ionic compounds are electrically neutral even though they are composed of cations and anions.

In ionic compounds, electrons are transferred according to the ***octet rule***, which states that in forming compounds, atoms tend to move toward the electron configuration of a noble gas.

Electron dot formulas are diagrams that represent the bonding of atoms to achieve the octet rule. Electron dot notation depicts valence electrons as dots around the atomic symbols of the elements in a compound.

1. Construct electron dot formulas to illustrate the ionic bonds for the compounds formed from each pair of elements below.

   i. Sodium and oxygen

   ii. Aluminum and sulfur

12.04

Electron Dot Formulas in Covalent Compounds

In covalent bonds, atoms move toward the electron configuration of noble gases by sharing electrons.

A ***structural formula*** is a diagram that represents how atoms are arranged in a molecule, with bonds represented by dashes.

- ***Unshared pair*** – A pair of valence electrons that is not shared between atoms
- ***Single covalent bond*** – A bond that involves one shared pair of electrons
- ***Double covalent bond*** – A bond that involves two shared pairs of electrons
- ***Triple covalent bond*** – A bond that involves three shared pairs of electrons

Guidelines for Constructing Electron Dot Formulas to Illustrate Covalent Bonds

- Arrange the elements symmetrically.
    - If there is only one atom, then that is the central atom.
    - If there is more than one atom, then the least electronegative element is placed in the center.
        - When a carbon atom is present, then that should be the central atom.
        - Hydrogen should never be the central atom.
- Join the outer elements to the central element with single, double, or triple covalent bonds.

1. How many unshared pairs are in the correct electron dot formula of NF_3?

    A. 12
    B. 8
    C. 10
    D. 9

Exceptions to the Octet Rule

The octet rule cannot be satisfied in all molecules.

- ***Hydrogen*** requires two electrons to satisfy its octet.
- ***Beryllium*** requires four electrons to satisfy its octet, but it can have up to eight electrons.
- ***Boron*** requires six electrons to satisfy its octet, but it can have up to eight electrons.
- Some elements have an odd number of valence electrons, so their electron dot formulas have lone electrons on them.
- Certain elements, such as phosphorous and sulfur, can have more than eight electrons to fill their octets because they can use ***d-orbitals*** to make the bonds.

2. Construct electron dot formulas to illustrate the covalent bonds in the following molecules:

   i. H_2O

   ii. BF_3

   iii. CO_2

12.05

Resonance Structures

Resonance structures are structural diagrams that chemists use to envision the bonding in molecules that cannot be adequately described using a single structural formula. The structures must be valid electron dot formulas with the same number of electron pairs for a molecule or ion.

1. Construct an electron dot formula to illustrate the covalent bonds in nitrogen dioxide, NO_2.

Each resonance structure above is an accurate representation of how this molecule might look.

- We can assume that the actual bonding in the molecule above is the average of the two electron dot formulas.
- The electron pairs do not actually resonate back and forth.
- The actual bonding is a hybrid, or mixture, of the extremes represented by the resonance forms.

12.06

VSEPR Molecular Geometry/Shape

In ***valence shell electron pair repulsion (VSEPR) theory*****,** the 3-D shape of a molecule is determined by the following steps:

1. Drawing the electron dot formula
2. Counting the number of electron groups around the central atom
3. Assigning an AXE configuration to the structure

The specific AX_mE_n formula, where *m* and *n* are integers, tells us the shape of the molecule or polyatomic ion.

- *A* is the central atom.
- *X* represents the number of atoms around the central atom (i.e., bonding sites).
- *E* is the number of lone pairs of electrons around the central atom.

Electron Pair Geometry

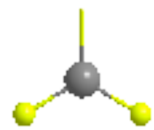
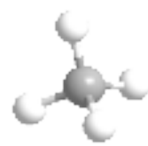
The shape made by the electron pairs around the central atom is described as the ***electron pair geometry***. There are three possible electron pair geometries: linear, trigonal planar, and tetrahedral.

Bond Angles

VSEPR theory states that the repulsion between electron pairs causes molecular shapes to adjust so that the valence electron pairs stay as far apart as possible.

- When the molecules are as far apart as possible, there is a measurable bond angle between the central element and two peripheral elements.
- If there are unshared pairs of electrons on molecular shapes, the bond angle is affected.

Some Examples of Molecular Geometries/Shapes

Two Electron Groups (Linear Electron Pair Geometry)	
AX_2: Linear Molecular Geometry (180°)	
Three Electron Groups (Trigonal Planar Electron Pair Geometry)	
AX_3: Trigonal Planar Molecular Geometry (120°)	
AX_2E_1: Bent Molecular Geometry (117°)	
Four Electron Groups (Tetrahedral Electron Pair Geometry)	
AX_4: Tetrahedral Molecular Geometry (109.5°)	
AX_3E_1: Trigonal Pyramidal Molecular Geometry (107°)	
AX_2E_2: Bent (Water Bent) (105°)	

1. The shape of H_2CO is ______________________.

    A. tetrahedral
    B. trigonal planar
    C. trigonal pyramidal
    D. linear

2. Use VSEPR theory to predict bond angles in ammonia.

PERIODIC TABLE OF THE ELEMENTS

	1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	<--- 8	8B 9	---> 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Ha (262)	106 (263)	107 (262)	108	109									

Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)