Molecular Modeling
Computational Chemistry

http://molview.org

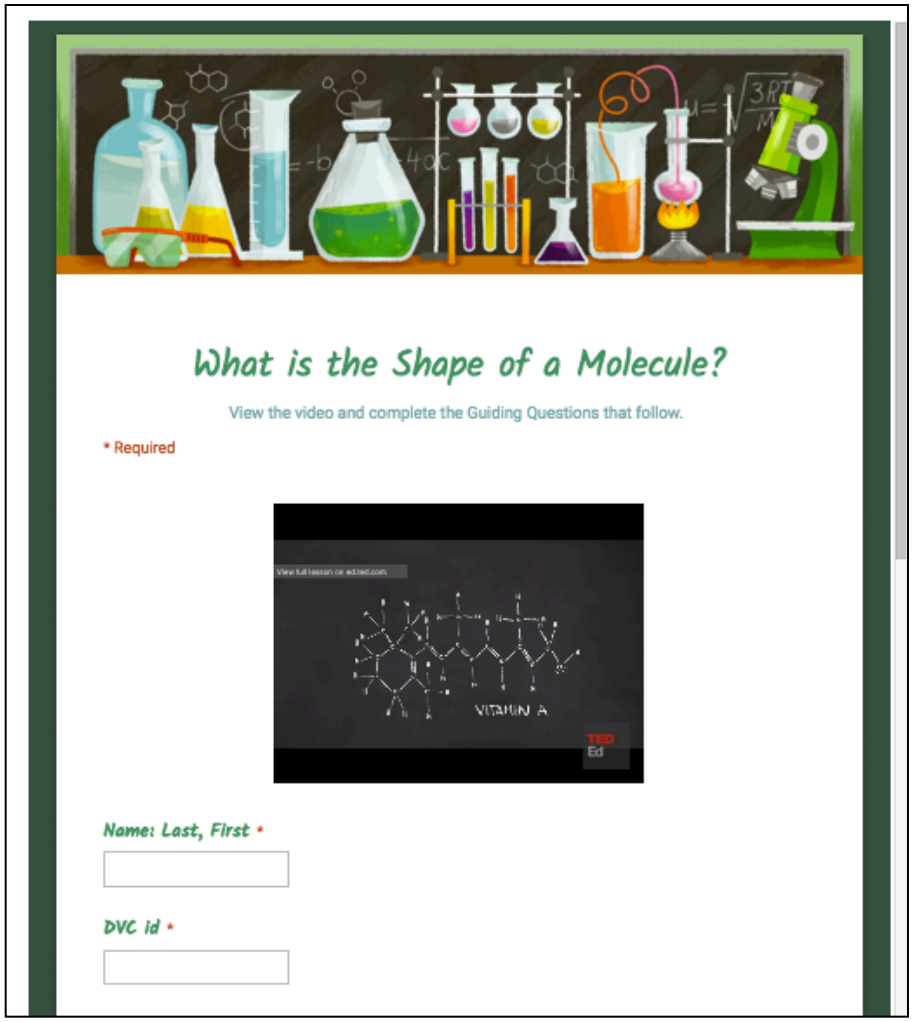
Shapes ⟷ Lewis Structures

Covalent Bonds:
Lewis Structures, Molecular Shapes

Dr. Ron Rusay

https://www.youtube.com/watch?v=Jq_Ca-HKh1g

Shapes of Molecules

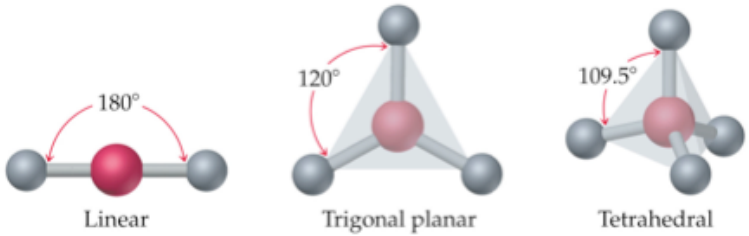


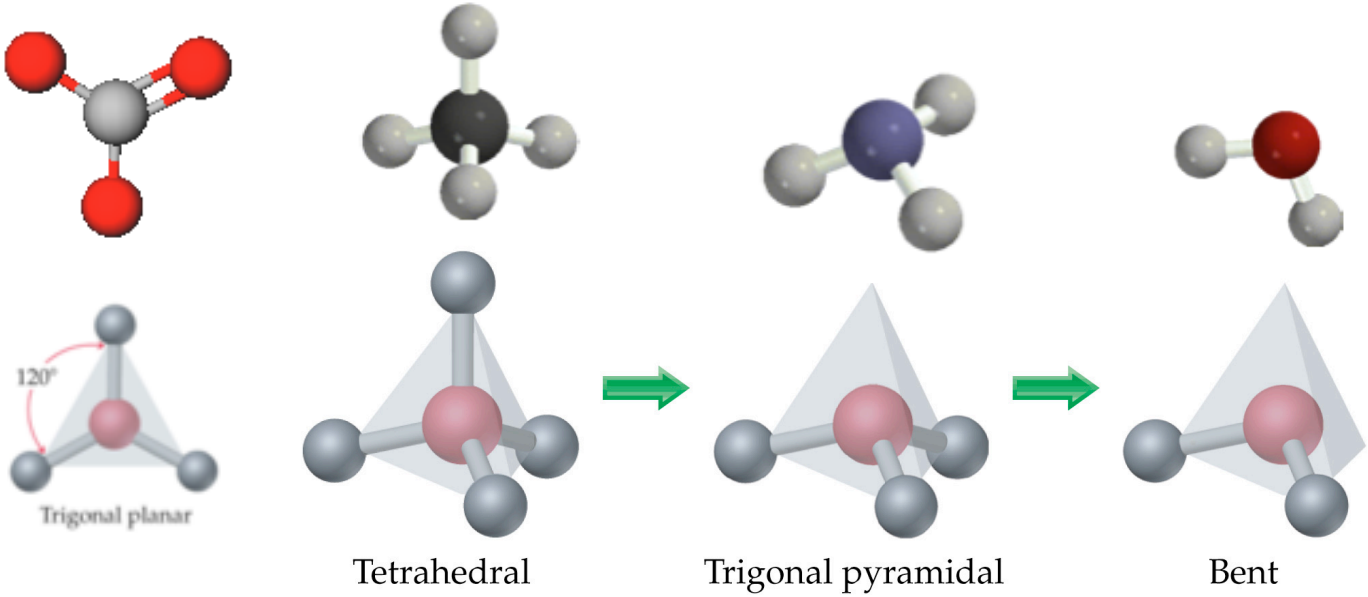
View: What is the shape of a molecule?
George Zaidan and Charles Morton

http://chemconnections.org/general/chem108/Molecular%252520Shapes-Guide.html

Molecular Shapes
Molecular Models for C, H, N, O

- Fundamental repeating shapes found in every biological and synthetically made organic molecule including plastics

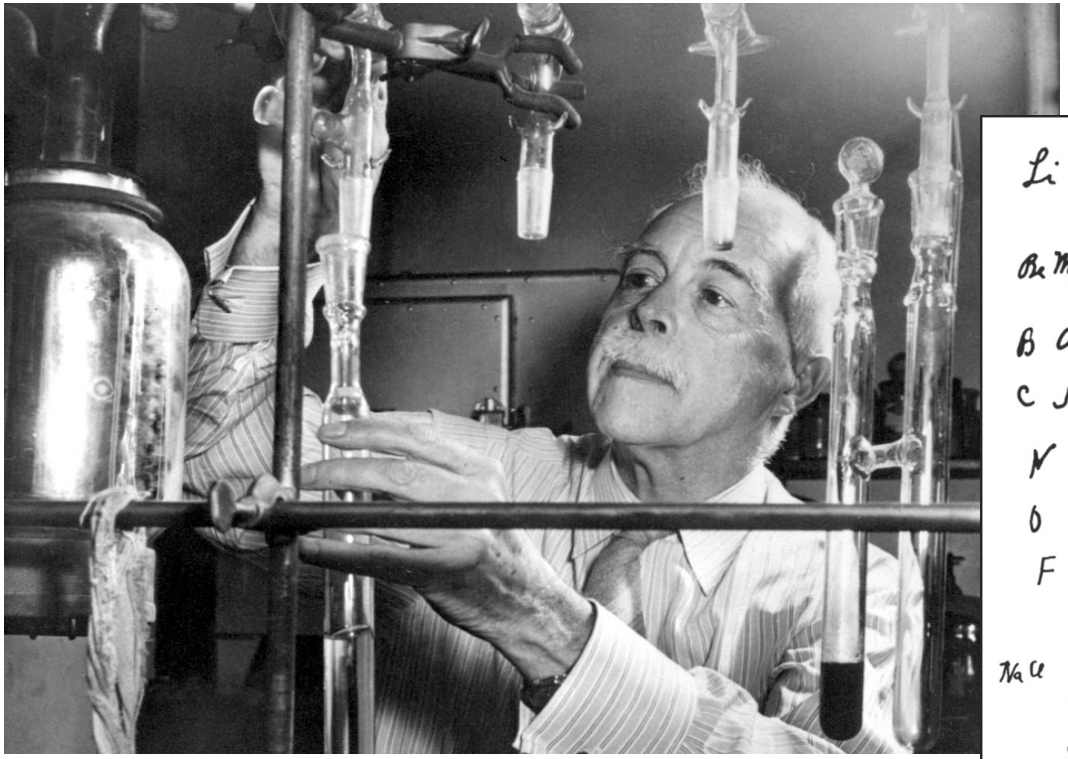


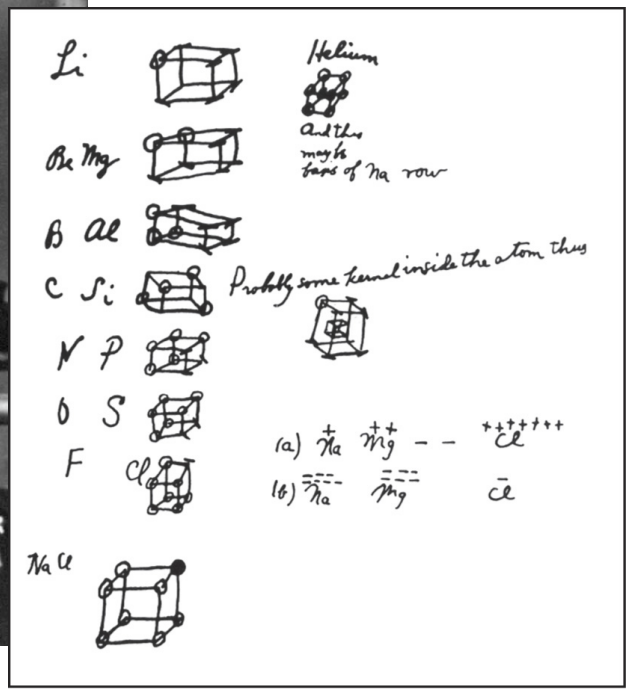


C =black
H = gray
N = blue
O = red

pink = generic atom

Professor Gilbert Newton Lewis (circa 1940)



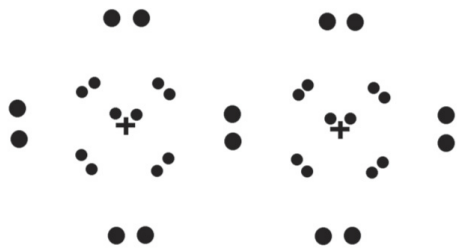


G.N. Lewis

Photo Bancroft Library, University of California/LBNL Image Library

Footnote:

G.N. Lewis, despite his insight and contributions to chemistry, was never awarded the Nobel prize.



Notes from Lewis's notebook and his "Lewis" structure.

Valence Electrons – Lewis Dot Drawings

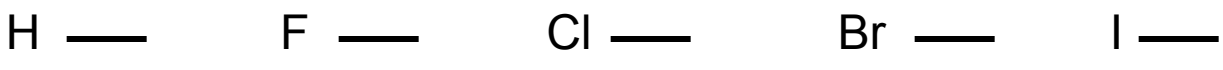
A Groups-Periods 2 & 3

Period	1A(1) ns^1	2A(2) ns^2	3A(13) ns^2np^1	4A(14) ns^2np^2	5A(15) ns^2np^3	6A(16) ns^2np^4	7A(17) ns^2np^5	8A(18) ns^2np^6
2	Li	Be	B	C	N	O	F	Ne
3	Na	Mg	Al	Si	P	S	Cl	Ar

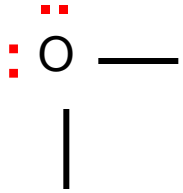
Covalent Bond Numbers

(Neutral Atoms!)

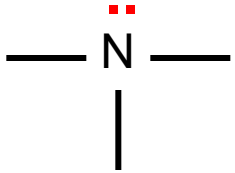
one bond



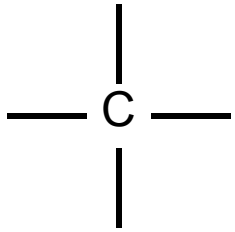
two bonds



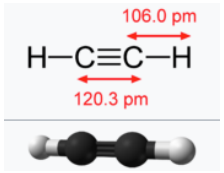
three bonds

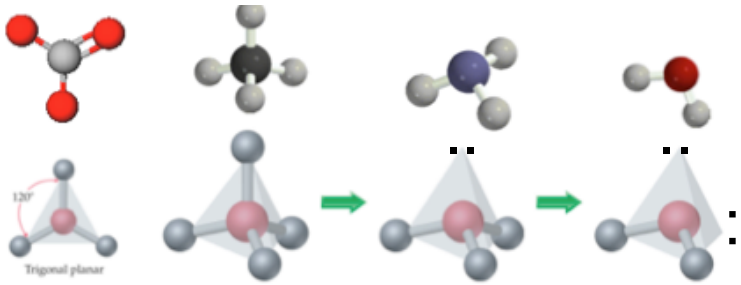


four bonds



Linear | Trigonal Planar | Tetrahedral | Trigonal Pyramidal | Bent





Linear | Trigonal Planar | Tetrahedral | Tetrahedral | Tetrahedral

Molecular Models [Handout]

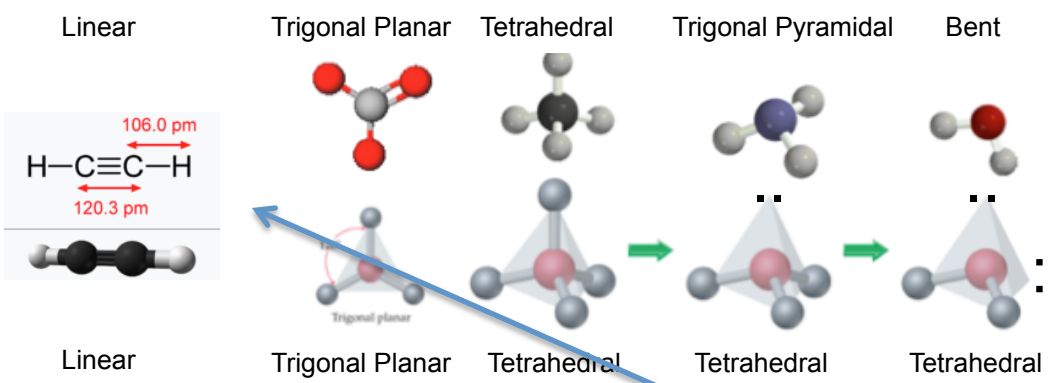
molecular shape

"electronic"="VSEPR" shape includes the electron pairs (VSEPR: Electron Domain)

Symbol	Valence electrons	Number of Bonds	Types	Shape	
				electronic	molecular
C	4	4	4 single		
		4	2 single + 1 double		
		4	1 single + 1 triple		
H	1	1	1 single		
O	6	2	1 double		
		2	2 single		
N	5	3	3 single		
		3	1 single + 1 double		
		3	1 triple		

http://chemconnections.org/general/chem108/Molecular%20Modeling-intro%20%26%20table%202019f.pdf

Molecular Models [Handout]



molecular shape

"electronic"="VSEPR" shape includes the electron pairs (VSEPR: Electron Domain)

Linear = L

Trigonal Planar = TPl

Tetrahedral =T

Trigonal Pyramidal =TPy

Bent = B

Symbol	Valence electrons	Number of Bonds	Types	Shape	
				electronic	molecular
C	4	4	4 single	T	T
		4	2 single + 1 double	TPl	TPl
		4	1 single + 1 triple	L	L
H	1	1	1 single	L	L
O	6	2	1 double	TPl	L
		2	2 single	T	B
N	5	3	3 single	T	TPy
		3	1 single + 1 double	TPl	B
		3	1 triple	L	L

carbon-carbon bond lengths

Single
longest length

Double
shorter length

Triple
shortest length

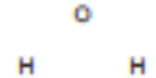
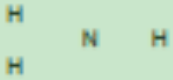
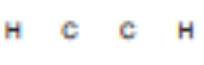
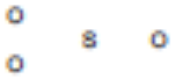
http://chemconnections.org/general/chem108/Molecular%20Modeling-intro%20%26%20table%202019f.pdf

http://molview.org

Lewis Structures ⟷ Molecular Shapes

Name?
Ammonia

Report Form – Molecular Models

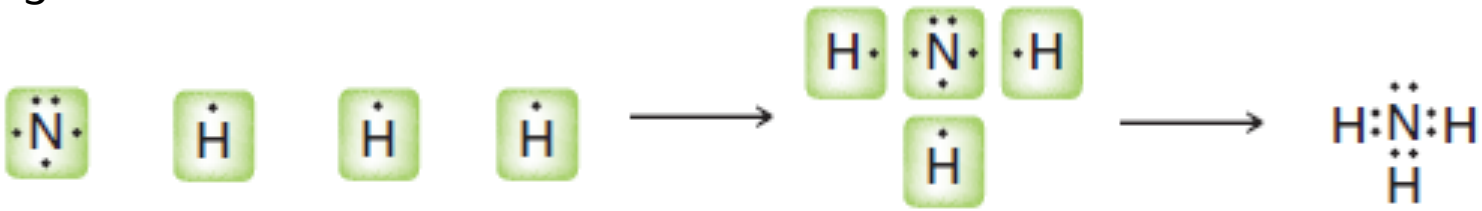
Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non–Polar)	Molecule (Polar or Non–Polar)	3 Dimensional Drawing	Resonance (Yes or No)
H_2O						Polar		No
NH_3	8					Polar		No
CH_4								No
C_2H_4			Around each C	Around each C	C–H C–C	Non–Polar		No
HCN			Around C	Around C	H–C C–N	Polar		No
C_2H_2			Around each C	Around each C	C–H C–C			No
SO_3						Non–Polar		Yes

Molecular Modeling: Bonding & Lewis Structures

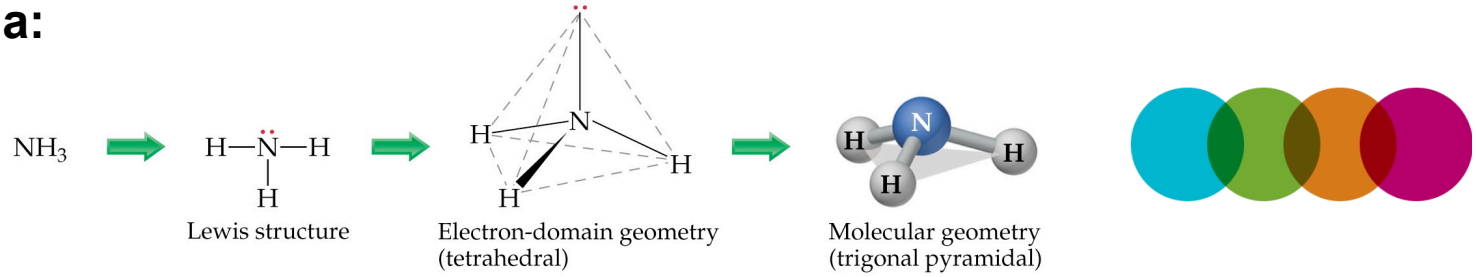
Computational Chemistry: Molecular Modeling Report Form

Lewis Structures ⟷ Molecular Shapes

- For simple Lewis structures:
  1. Draw the individual atoms using dots to represent the valence electrons.
  2. Put the atoms together so they share PAIRS of electrons to make complete octets.
- NH_3, for example:



Eg. Ammonia:

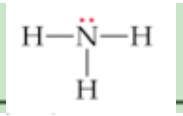
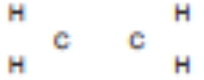


http://molview.org

Molecular Shapes ⟷ Lewis Structures

Name?
Ammonia

Report Form – Molecular Models

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non-Polar)	Molecule (Polar or Non-Polar)	optional 3 Dimensional Drawing	Resonance (Yes or No)
H_2O						Polar		No
NH_3	8					Polar		No
CH_4								No
C_2H_4			Around each C	Around each C	C–H C–C	Non-Polar		No
HCN			Around C	Around C	H–C C–N	Polar		No
C_2H_2			Around each C	Around each C	C–H C–C			No
SO_3						Non-Polar		Yes

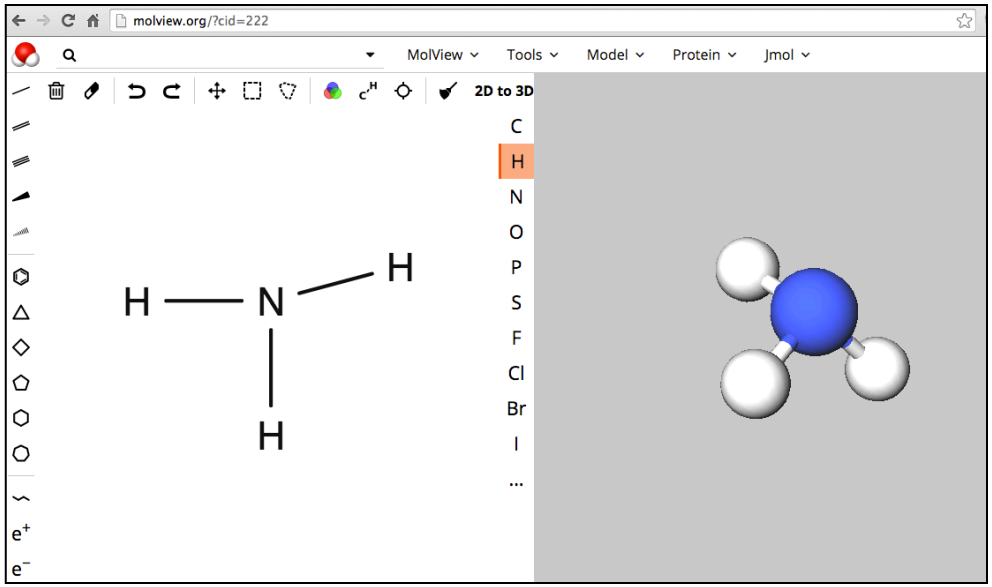
Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

http://molview.org

Molecular Shapes ⟷ Lewis Structures

MolView: Visual On-line Molecular Modeling

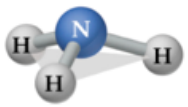
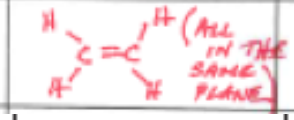


Bonding, Lewis Structures, Molecular Modeling:
Computational Experiments

http://molview.org

Molecular Shapes ⟷ Lewis Structures

Report Form – Molecular Models

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non-Polar)	Molecule (Polar or Non-Polar)	optional 3 Dimensional Drawing	Resonance (Yes or No)
H_2O		O H H				Polar		No
NH_3	8	H—N—H H	Tetra-hedral	Trigonal Planar		Polar		No
CH_4		H H C H H						No
C_2H_4	12	H H C : : C H H				Non-Polar		No
HCN		H C N			C–N	Polar		No
C_2H_2		H C C H	Around each C	Around each C	C–H C–C			No
SO_3		O O S O				Non-Polar		Yes

Name?
Ammonia

ethylene

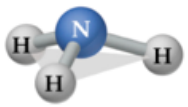
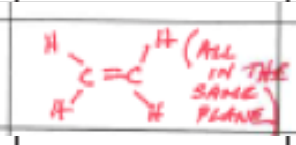
Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

http://molview.org

Molecular Shapes ⟷ Lewis Structures

Report Form – Molecular Models

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non-Polar)	Molecule (Polar or Non-Polar)	optional 3 Dimensional Drawing	Resonance (Yes or No)
H_2O		O H H				Polar		No
NH_3	8	H—N—H H	Tetra-hedral	Trigonal Planar		Polar		No
CH_4		H H C H H						No
C_2H_4	12	H H C : : C H H	Around each C TRIGONAL PLANAR	Around each C TRIG-PLANER		Non-Polar		No
HCN		H C N			C–N	Polar		No
C_2H_2		H C C H	Around each C	Around each C	C–H C–C			No
SO_3		O O S O				Non-Polar		Yes

Name?
Ammonia

ethylene

Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

http://molview.org

Molecular Shapes ⟷ Lewis Structures

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non–Polar)	Molecule (Polar or Non–Polar)	3 Dimensional Drawing	Resonance (Yes or No)
N_2		N N						No
Ammonium $(NH_4)^+$		H H N H H				Polyatomic Ion		No
PBr_3		Br P Br Br				Polar		No
$(NO_2)^-$		O N O				Polyatomic Ion		Yes
$(CO_3)^{2-}$		O C O O				Polyatomic Ion		Yes
CH_2O		O C H H						No

Molecular Modeling: Bonding & Lewis Structures

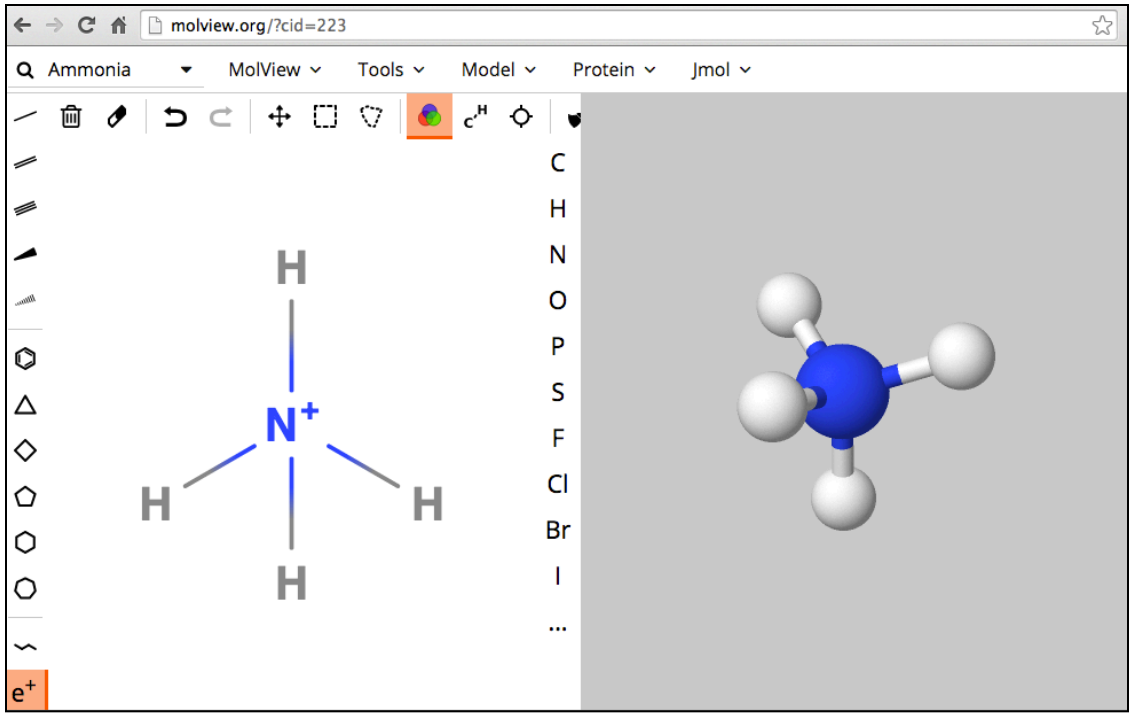
Computational Chemistry: Molecular Modeling Report Form

http://molview.org

Molecular Shapes ⟷ Lewis Structures

MolView: Visual On-line Molecular Modeling

Ammonium
(polyatomic ion)



Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

VSEPR (Electronic) Geometry	Molecular Geometry	Bond Angle	# of lone pairs
Linear	Linear	180°	0
Trigonal Planar	Trigonal Planar	120°	0
Trigonal Planar	Bent	<120°	1
Tetrahedral	Tetrahedral	109.5°	0
Tetrahedral	Trigonal Pyramidal	<109.5°	1
Tetrahedral	Bent	<109.5°	2
Trigonal Bipyramidal	Trigonal Bipyramidal	120°, 90°	0
Trigonal Bipyramidal	Seesaw	<120°, <90°	1
Trigonal Bipyramidal	T-shape	<90°	2
Trigonal Bipyramidal	Linear	180°	3
Octahedral	Octahedral	90°	0
Octahedral	Square Pyramidal	<90°	1
Octahedral	Square Planar	90°	2

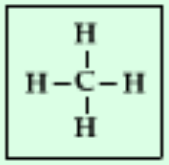
Important in Organic Compounds

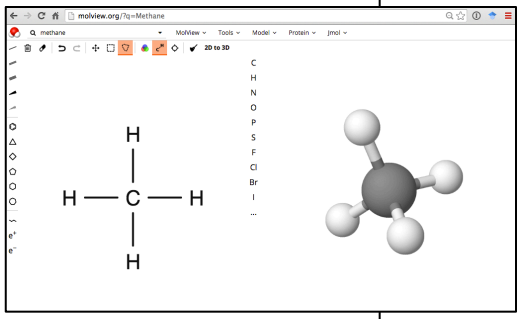
See again in Chem 120 and possibly in Chem 109

http://chemconnections.org/general/movies/Lewis%20structures.html

chemconnections.org/general/movies/Lewis%20structures.html

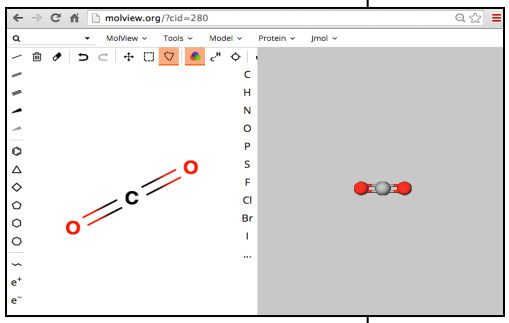
CH_4

Click for total number of valence electrons.	4+(4x1) = 8 Click again for skeleton.	 Click again to subtract 2 electrons for each bond.	4 x 2 = 8 8 electrons used in bonds. 8 - 8 = 0 remaining to distribute. Click again to see final Lewis structure.	 CH_4



CO_2

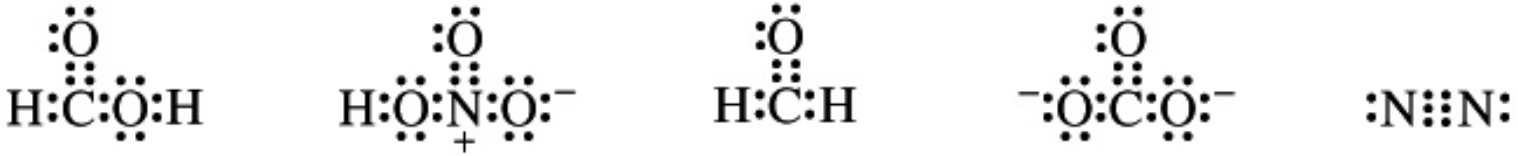
Click for total number of valence electrons.	4+(2x6) = 16 Click again for skeleton.	O—C—O Click again to subtract 2 electrons for each bond.	2 x 2 = 4 4 electrons used in bonds. 16 - 4 = 12 remaining to distribute. Click to distribute the remaining electrons.	:Ö—C—Ö: Click to complete carbon's octet by formation of double bonds.	Ö = C = Ö CO_2



Lewis Structures / Covalent Compounds

- Share valence electrons.
- 1 pair = 1 bond; maximum # of atom-atom bonds = 3.
- Octet rule ("duet" for hydrogen)
- Lewis structure examples:

Lewis structures



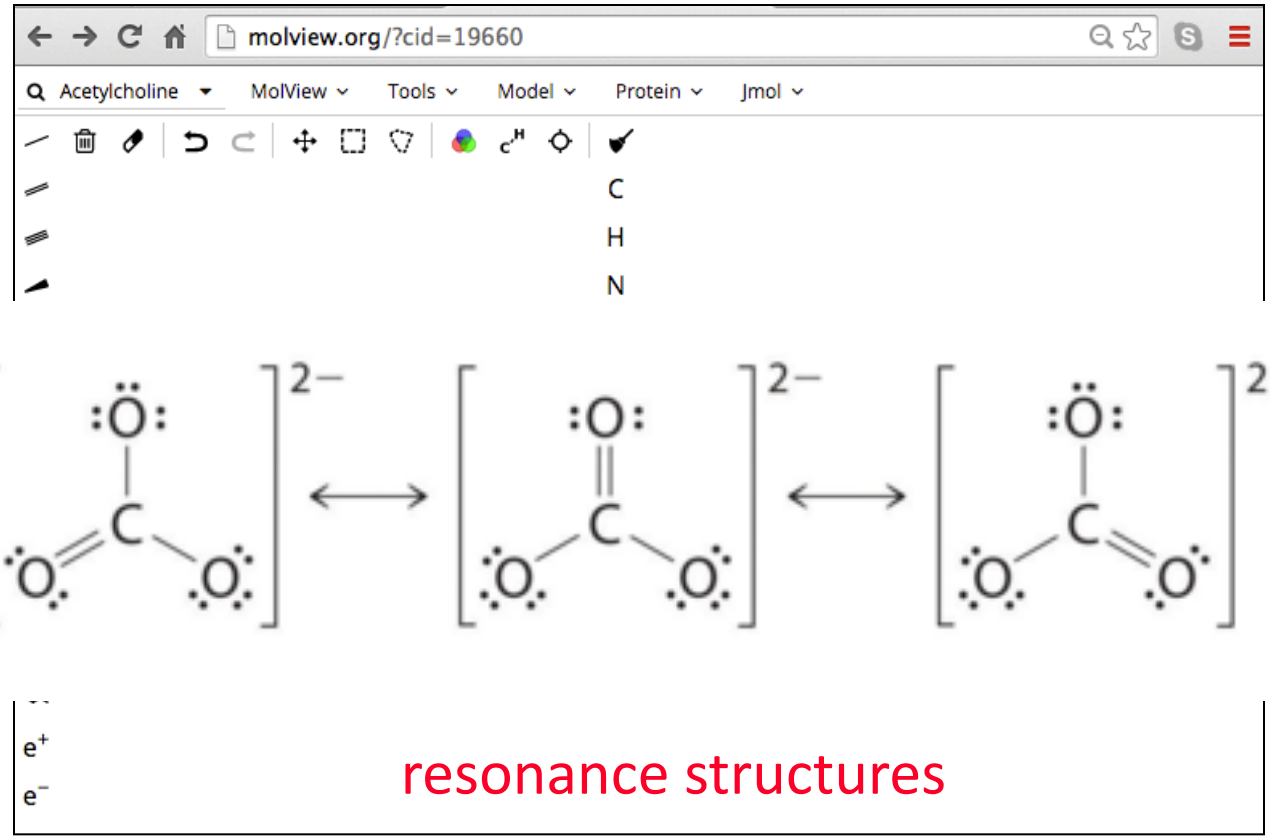
Notice the "formal" charges:
In one case they balance, can you name the compound?
In the other they do not.

They both have "formal" charges. Can you name the polyatomic ion?

http://molview.org

Resonance Models & Lewis Structures

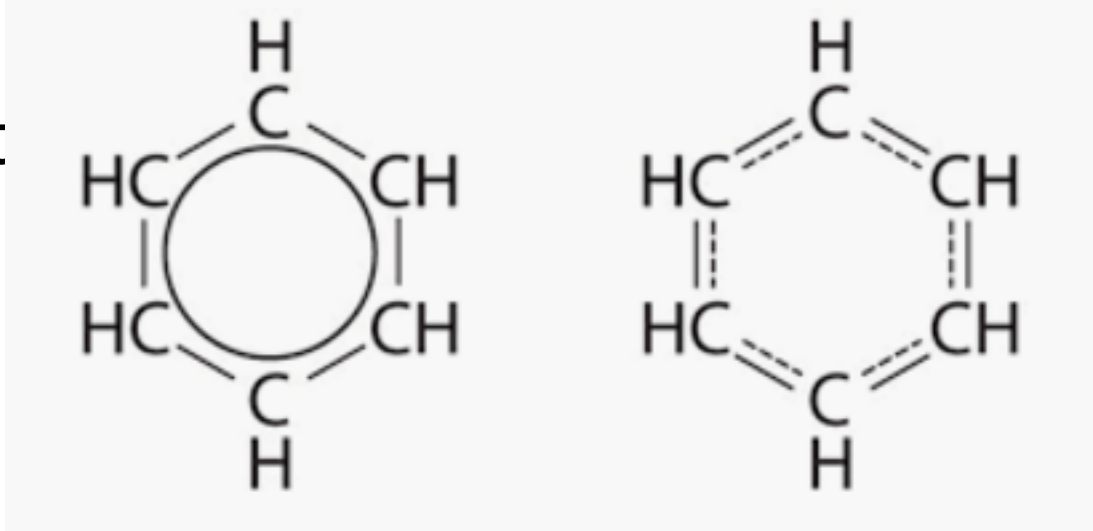
MolView: Carbonate Polyatomic Ion



Bonding, Lewis Structures, Molecular Modeling:

Resonance

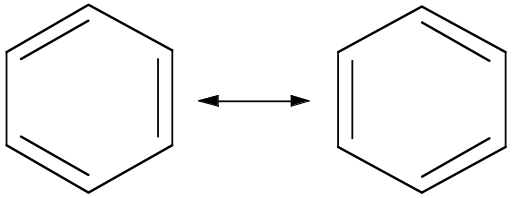
- Occurs when more than one valid Lewis structure can be written for a particular mo double or t



- An overall resonance structure is a weighted average of all of the possible resonance structures.

Question

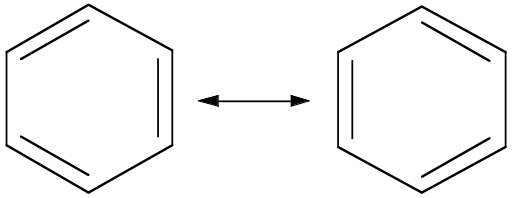
Two resonance structures of benzene, a human carcinogen, with C-C & C=C bonds are shown below. Which statement is incorrect?



A. The double headed arrow indicates that the 2 resonance structures are rapidly interchanging.
B. The normal bond length of a single bond is longer than a double bond.
C. The best resonance structure localizes the bonds so that the double bonds on the right are preferred.
D. The actual bond lengths in benzene are not equal to either single or double bonds.

Answer

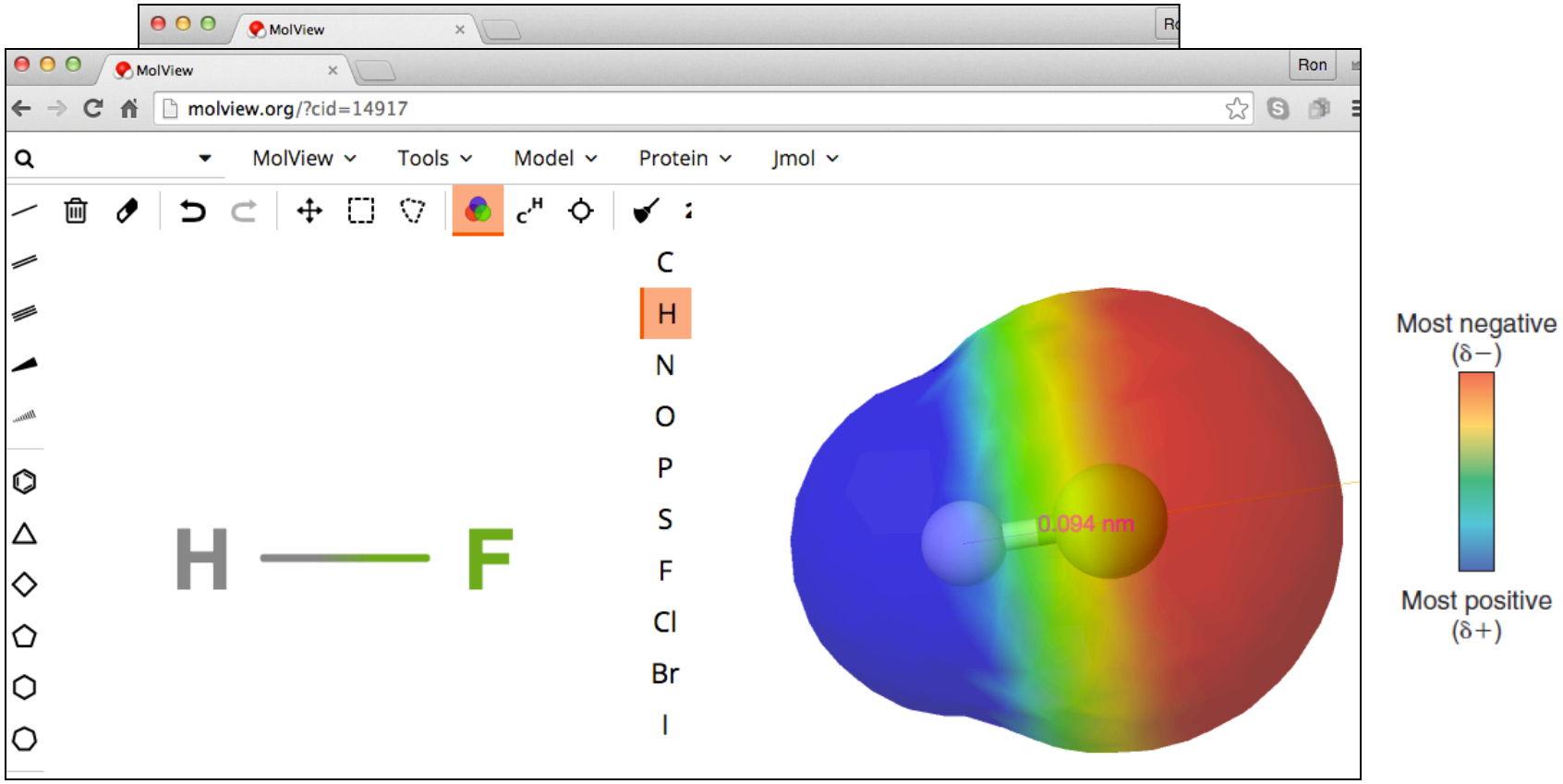
Two resonance structures of benzene, a human carcinogen, with C-C & C=C bonds are shown below. Which statement is incorrect?



A. The double headed arrow indicates that the 2 resonance structures are rapidly interchanging.
B. The normal bond length of a single bond is longer than a double bond.
C. The best resonance structure localizes the bonds so that the double bonds on the right are preferred.
D. The actual bond lengths in benzene are not equal to either single or double bonds.

Polarity & Modeling

Polarity: Molview (http://molview.org) Jmol



Color coded electron density distribution: red-highest, blue lowest, green balanced

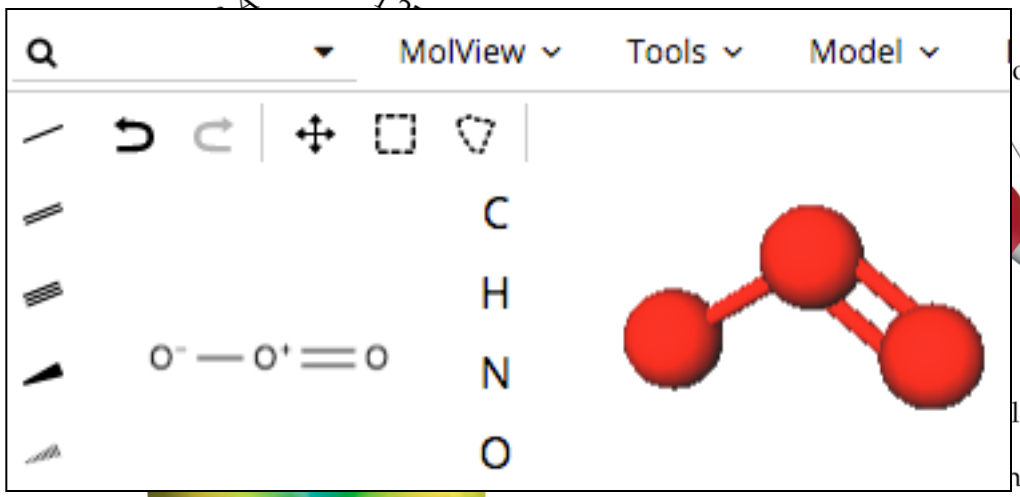
The more distinct the red –blue colors means the more polar the molecule.

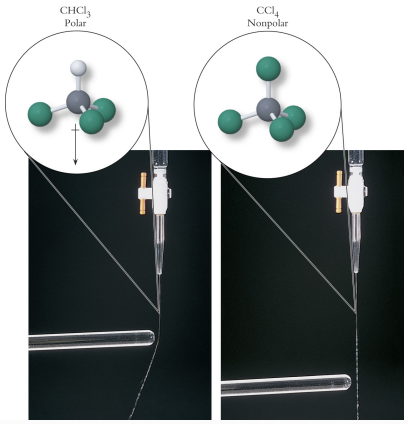
https://www.youtube.com/watch?v=ASLUY2U1M-8

Polarity & Physical Properties

Ozone, Water, & Batteries

0.1278 nm

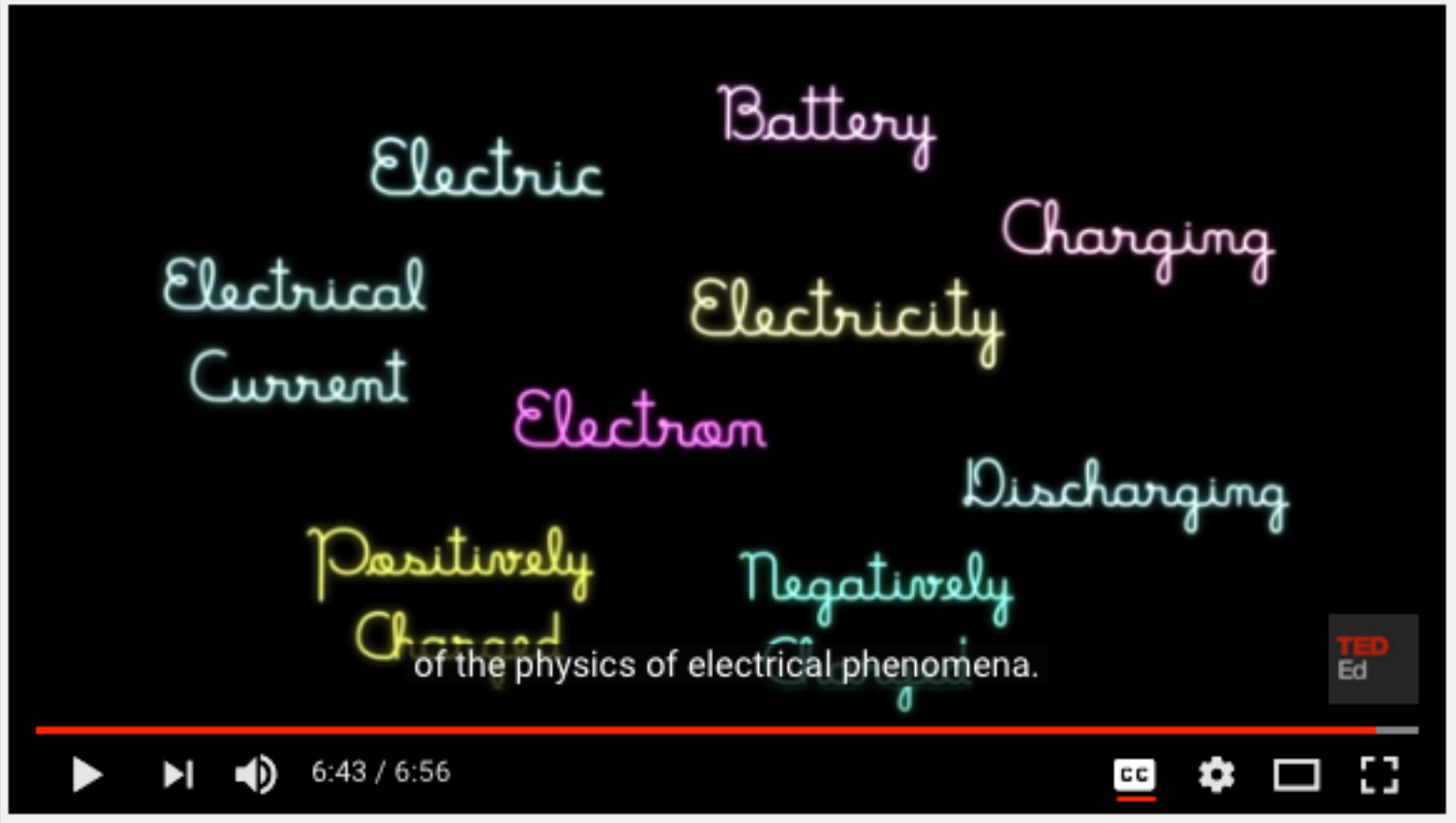




- Resultant Molecular Dipoles > 0
- Solubility: Polar molecules that dissolve or are dissolved in like molecules

- The Lotus flower
- Water & dirt repellancy: solubility?

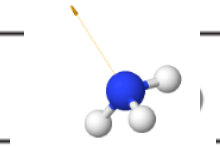
https://www.youtube.com/watch?v=MBRTR2dlwvA&t=244s



http://molview.org

Molecular Shapes ⟷ Lewis Structures

Report Form – Molecular Models

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non-Polar)	Molecule (Polar or Non-Polar)	optional 3 Dimensional Drawing	Resonance (Yes or No)
H_2O		O H H				Polar		No
NH_3	8	H—N—H (H)	Tetra-hedral	Trigonal Planar	Polar	Polar		No
CH_4		H H C H H						No
C_2H_4	12	H H C : : C H H	Around each C TRIGONAL PLANAR	Around each C TRIG-PLANER		Non-Polar		No
HCN		H C N			C–N	Polar		No
C_2H_2		H C C H	Around each C	Around each C	C–H C–C			No
SO_3		O S O O				Non-Polar		Yes

ammonia

ethylene

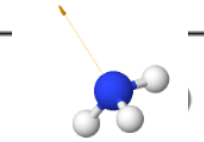
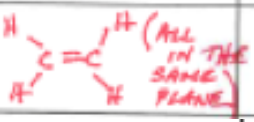
Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

http://molview.org

Molecular Shapes ⟷ Lewis Structures

Report Form – Molecular Models

Chemical Formula	# Valence e's in Molecule	Lewis Structure	Name of VSEPR Arrangement (Geometry)	Name of Shape (Molecular Geometry)	Bond (Polar or Non-Polar)	Molecule (Polar or Non-Polar)	optional 3 Dimensional Drawing	Resonance (Yes or No)
H_2O		O H H				Polar		No
NH_3	8	H—N—H (H)	Tetra-hedral	Trigonal Planar	Polar	Polar		No
CH_4		H H C H H						No
C_2H_4	12	H H C : : C H H	Around each C TRIGONAL PLANAR	Around each C TRIG-PLANAR	C–H NON POLAR C–C NON POLAR	Non-Polar		No
HCN		H C N			C–N	Polar		No
C_2H_2		H C C H	Around each C	Around each C	C–H C–C			No
SO_3		O O S O				Non-Polar		Yes

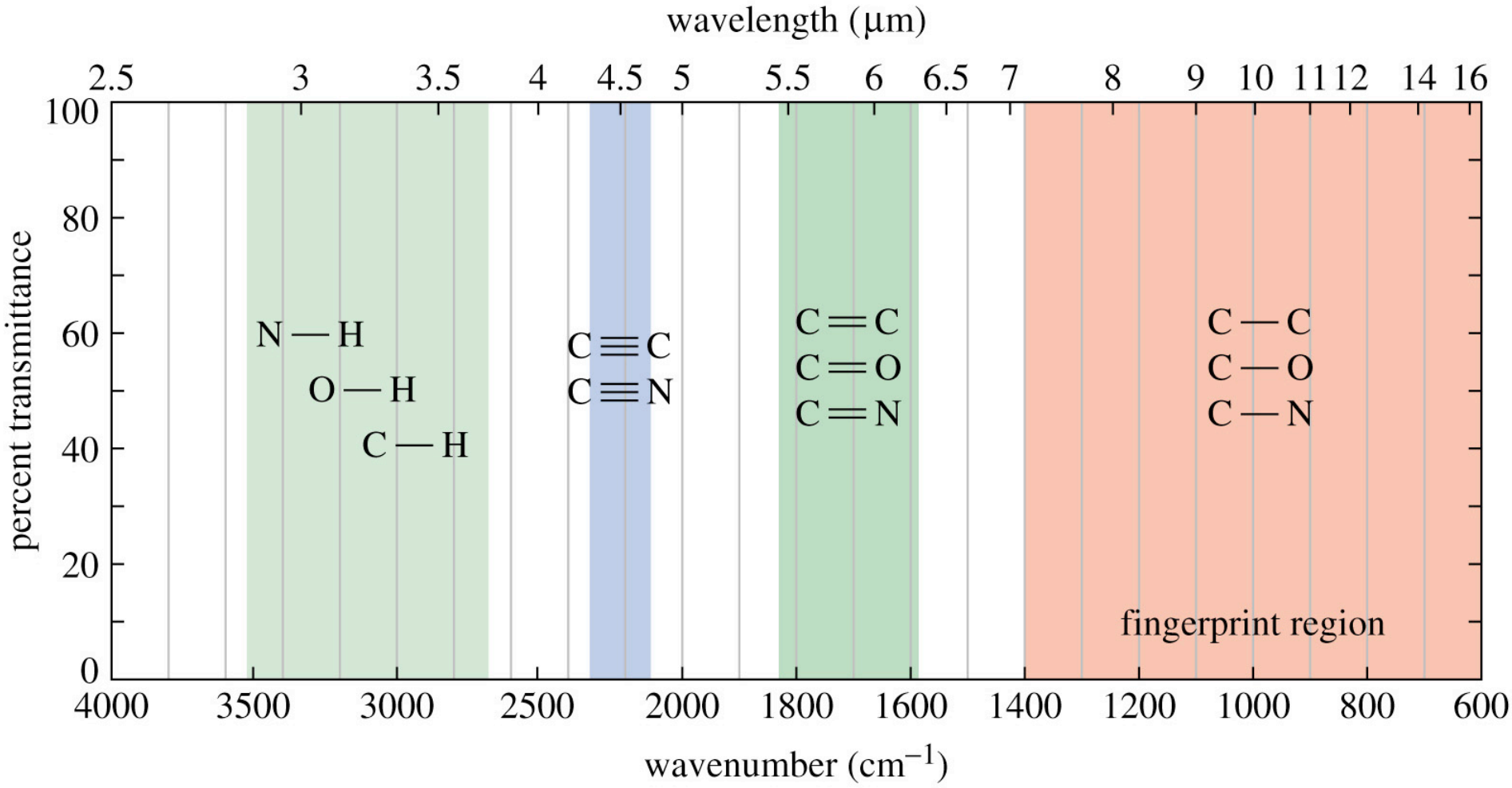
ammonia

ethylene

Molecular Modeling: Bonding & Lewis Structures

Computational Chemistry: Molecular Modeling Report Form

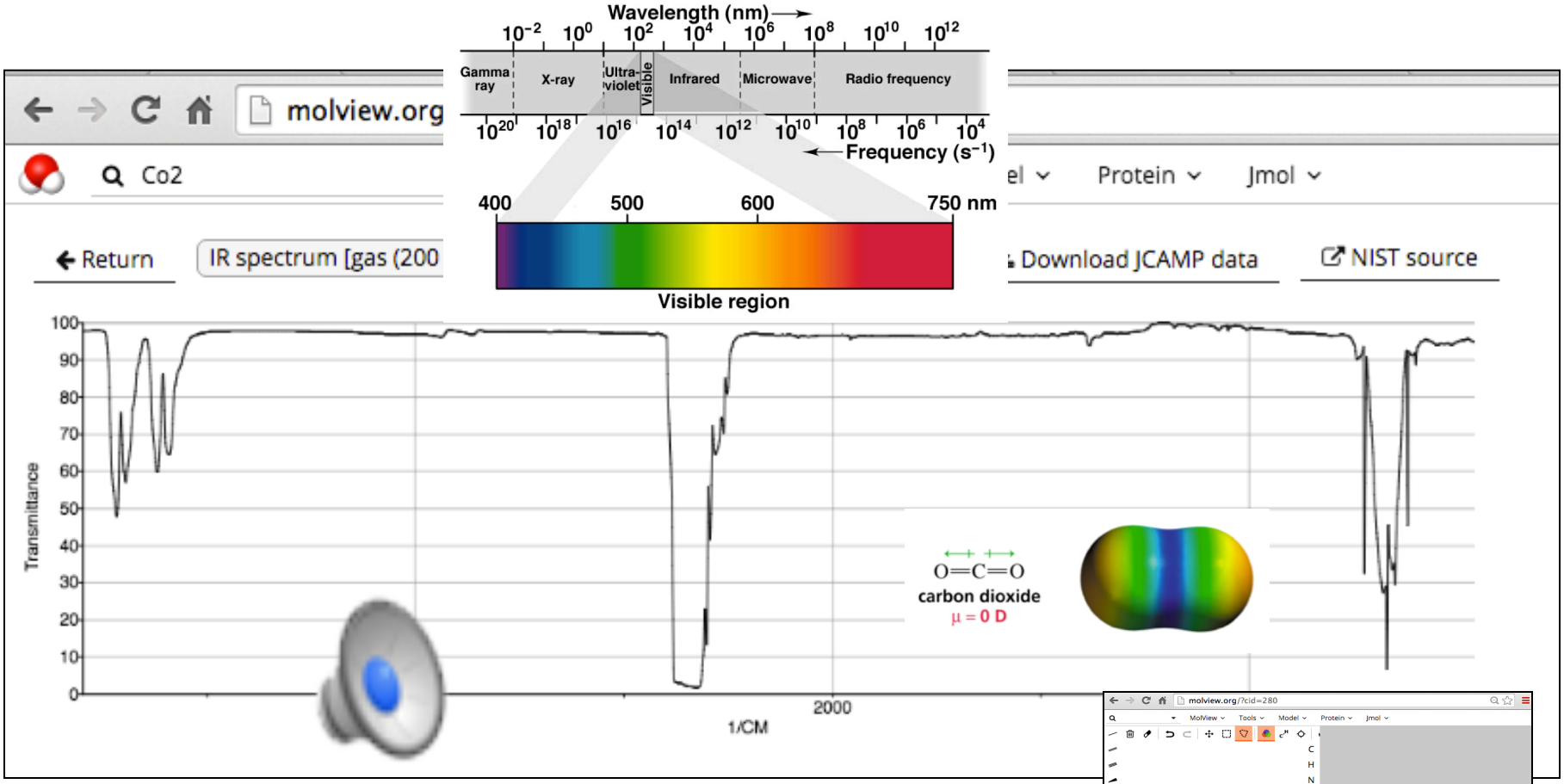
Infrared- Bond Absorbances

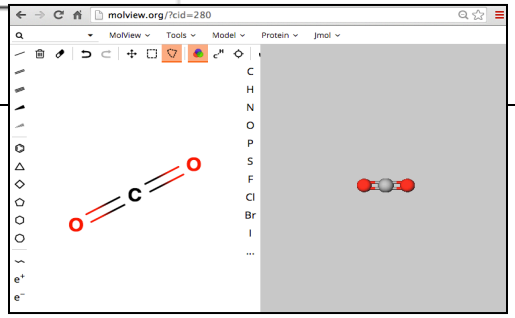


Invisible Molecular Motions:

https://www.youtube.com/watch?v=b0IbXG0hnOk

Infrared- Bond Absorbances

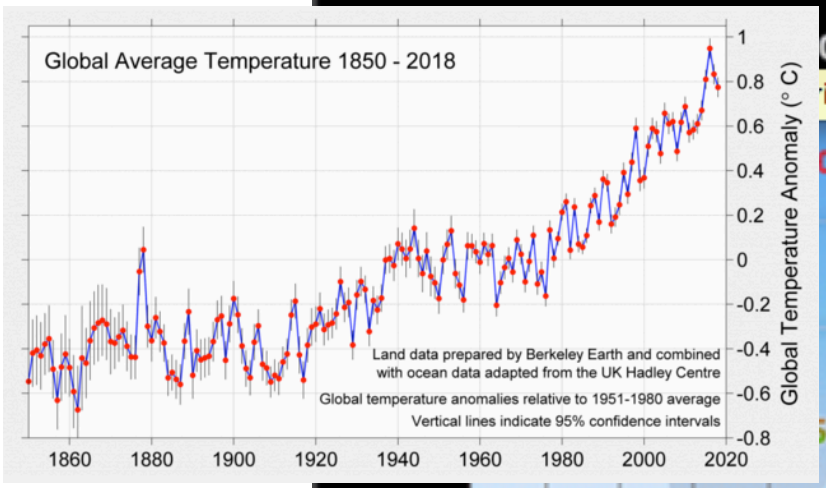


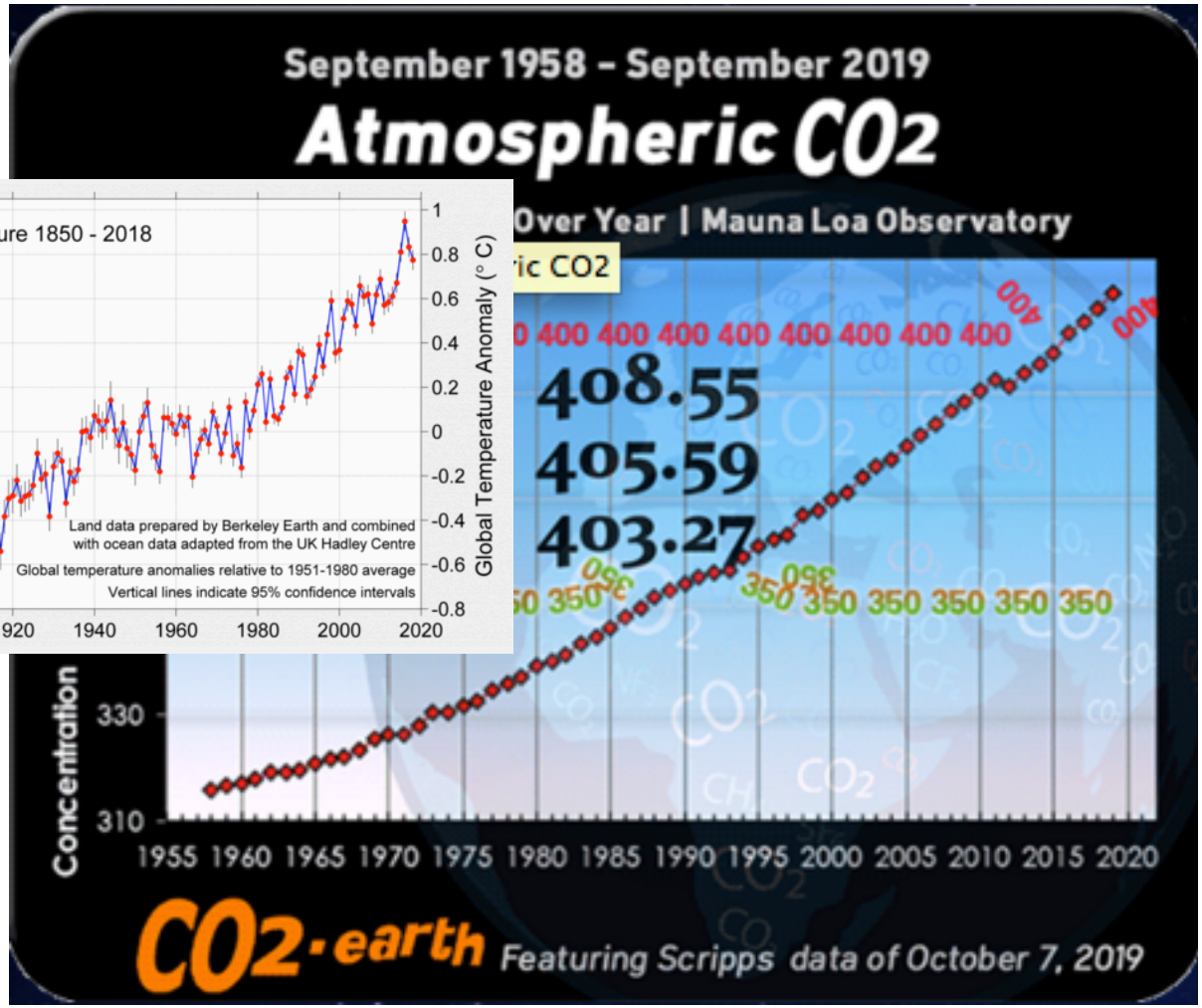


http://molview.org

https://www.youtube.com/watch?v=W5gimZlFY6I

Infrared- Bond Absorbances





https://www.co2.earth/