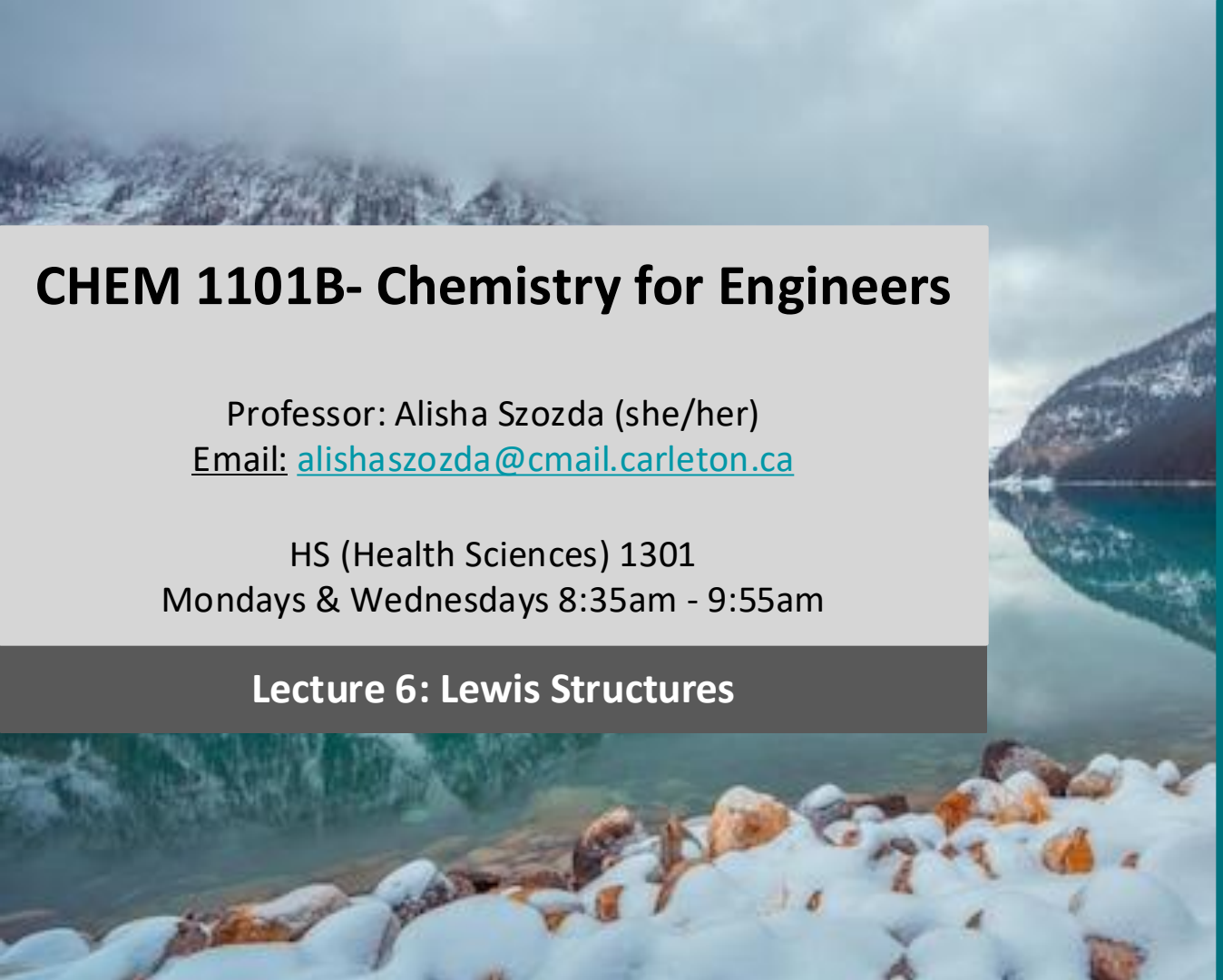


CHEM 1101B- Chemistry for Engineers

Professor: Alisha Szozda (she/her)
Email: alishaszozda@cmail.carleton.ca

HS (Health Sciences) 1301
Mondays & Wednesdays 8:35am - 9:55am

Lecture 6: Lewis Structures

Please feel free to introduce yourself to your neighbors– name, pronouns, a hobby, etc.

and/or

Answer the first question on Wooclap!

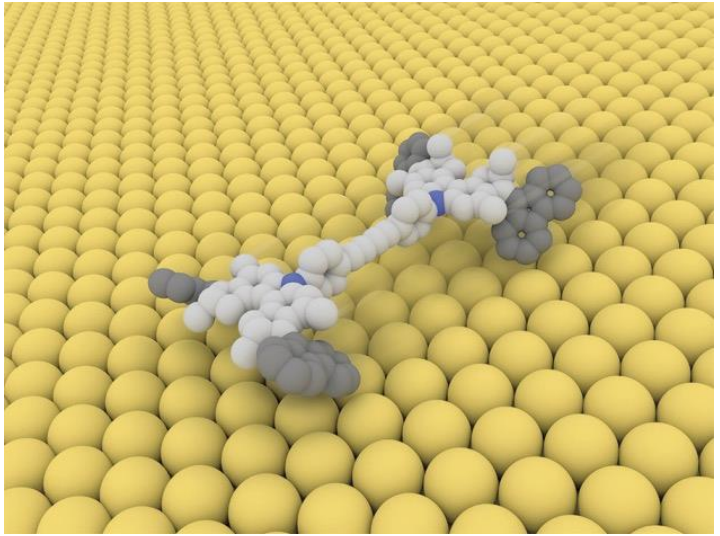
Learning outcome for Topic 6:
The Molecule – Lewis Structures

LO: Predict bonding arrangements and bond orders based on Lewis rules

The arrangement of electrons and chemical bonds in molecules gives us information about:

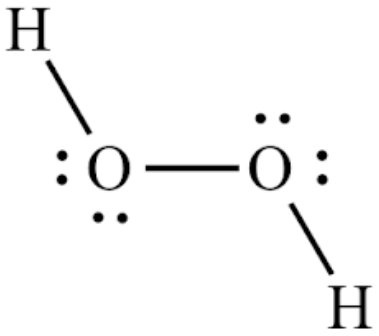
- Shape
- Physical properties
- Reactivity
- How to design molecular machines

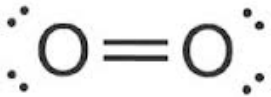
Nobel Prize in Chemistry, 2016 (Sauvage, Stoddart & Feringa) 'for the design and synthesis of molecular machines'
e.g., the nanocar

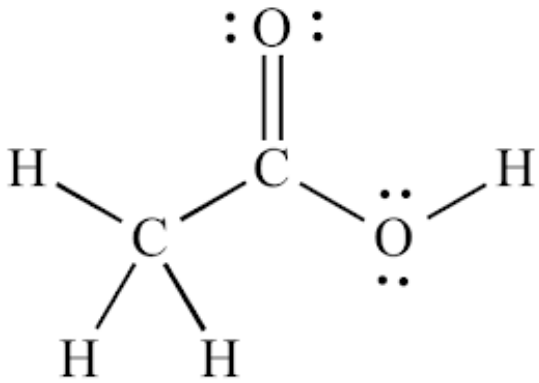


Lewis Electron-Dot Symbols

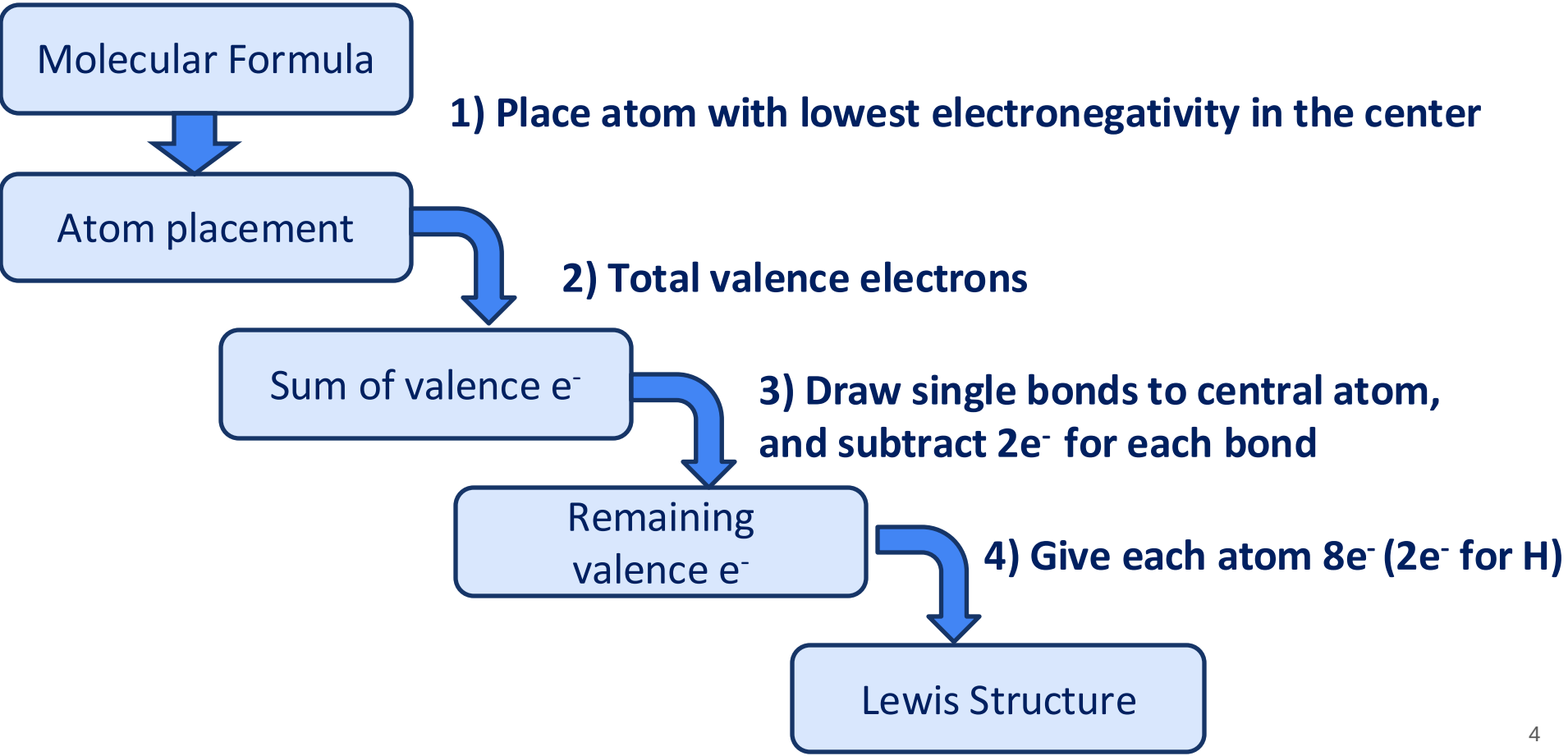
- Convenient representations of valence electrons
- Consists of the chemical symbol for the element plus a dot for each valence electron
- 2 electrons per side, 4 sides
- If all the sides are full, 8 electrons are in the the valence shell (stable octet)







Drawing Lewis Diagrams for Compounds



Example

Draw the Lewis structure for CH_2Cl_2

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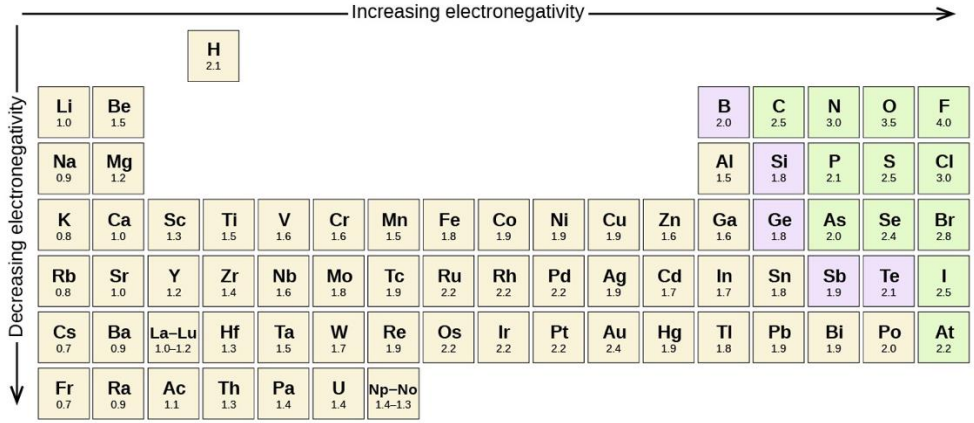
- Molecular Formula
- Atom placement
- Sum of valence e^-
- Remaining valence e^-
- Lewis Structure



How many total valence electrons are there?

a) 42
b) 13
c) 22
d) 20

When the central atom isn't clear, calculate formal charges!

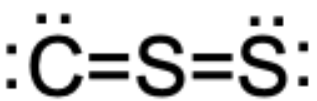
Formal charge:

- The charge an atom would have if all electrons were shared equally
- Must sum to the actual charge on the molecule

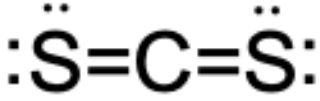
F.C. = # of valence e^- - (# of unshared valence e^- + 1/2 # of shared valence e^-)

Simpler: FC = # valence e^- - # of actual e^-

Example: Which is the correct Lewis structure for CS_2 (both EN = 2.5)?



OR



	C	S	S
Valence electrons			
Actual electrons			
Formal Charge			

	S	C	S
Valence electrons			
Actual electrons			
Formal Charge			

Lewis Structures for ions

- We can also draw Lewis structure of anions and cations
  - **Cations**: subtract 1 valence e^- for each + charge
  - **Anions**: add 1 valence e^- for each - charge
- To determine which atom(s) hold the charge(s), we can calculate the formal charge (F.C.) of each atom in the Lewis structure

Example: Draw the Lewis diagram for BF_4^- anion

Step 1: B more EN than F

Step 2:

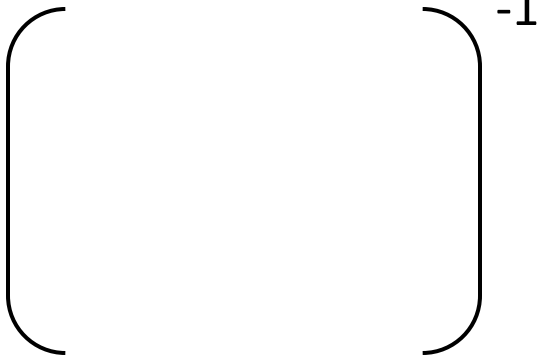
- B: 1 x $3e^-$ = 3
- F: 4 x $7e^-$ = 28
- -1: + $1e^-$ = 1

Total valence electrons = 32

Step 3: Remaining electrons

- 32 - (4bonds x $2e^-$) = 24

Step 4: complete octets with remaining electrons



F.C. of each F atom:

F.C. of the B atom:

Example: Cation

Draw the Lewis diagram for ICl_4^+

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Molecular Formula

Atom placement

Sum of valence e^-

Remaining valence e^-

Lewis Structure

Note: subtract 1 valence e^- for each + charge

What is the formal charge of Iodine?

a) +1
b) 0
c) -1
d) +2

Multiple Bonds (optimizing the octet)

- If there are not enough electrons to attain octets, a multiple bond (double or triple bond) is present
- **Oxygen, Carbon and Nitrogen** often form multiple bond
- Change lone pair on surrounding atom into another bonding pair to central atom

e.g. N_2

Example: Multiple Bonds

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Draw the Lewis structure for HCO_3^-, bicarbonate anion

Molecular Formula

Atom placement

Sum of valence e^-

Remaining valence e^-

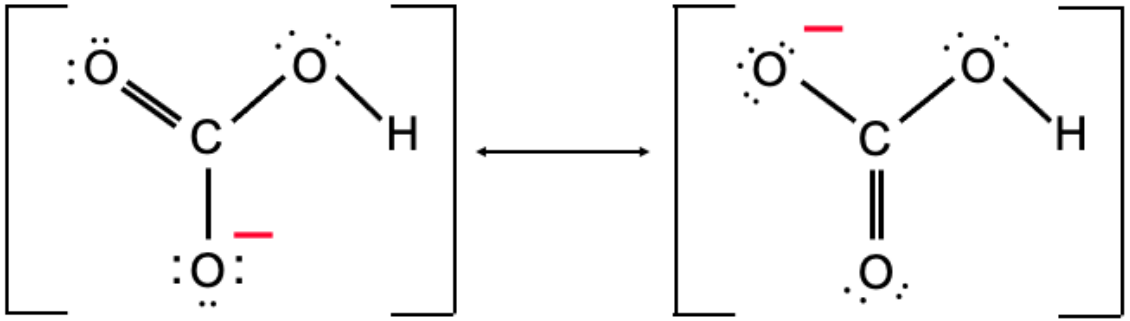
Lewis Structure

How many total valence electrons are there?

a) 20
b) 23
c) 22
d) 24

Resonance Structures

- **HCO_3^-** can be drawn in 2 ways:

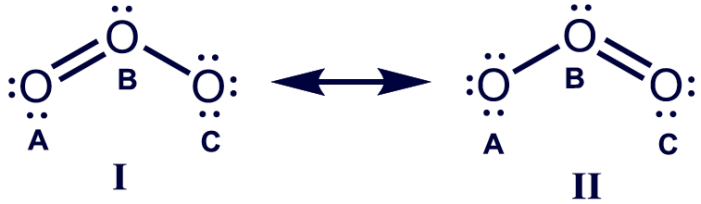


- There are two different reasonable Lewis Structures for the same molecule
- The formal charge is ”shared” between both oxygen atoms through resonance & must sum to the actual charge on the species for all resonance forms.
- Neither structure depicts HCO_3^- accurately, because in reality the two C-O bonds are identical in length and energy

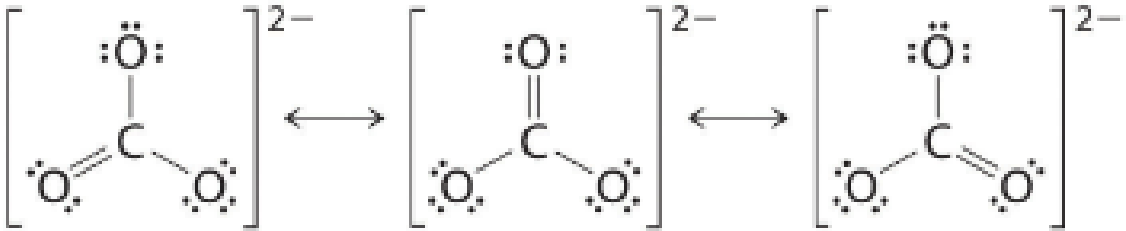
- **Bond order**: bond order of the identified bond in a resonance structure
  # of resonance structures

Other examples of resonance structures

O_3 can be drawn in 2 ways:



CO_3^{-2} can be drawn in 3 ways:



Choosing the more important resonance form

- Smaller formal charges (positive or negative) are preferable to larger ones.
- The same nonzero formal charges on adjacent atoms are not preferred
- A more negative formal charge should reside on a more electronegative atom.

e.g. NCO^-

Some exceptions to the Octet Rule

The octet rule applies for most compounds with period 2 central atoms

Exceptions exist for:

1. **Electron deficient atoms (e.g. Be, B, Al)**
   - Depends on electronegativity of atoms they are bonded to

2. **Odd electron atoms**
   - Free radicals e.g. NO_2 and NO

3. **Atoms with expanded valence shells**
   - Nonmetals from Period (row) 3 or higher (have d orbitals available)
   - e.g. SO_2

Example – atoms with expanded valence shells

Molecular Formula

Atom placement

Sum of valence e^-

Remaining valence e^-

Lewis Structure

Draw the lewis diagram for SF_6

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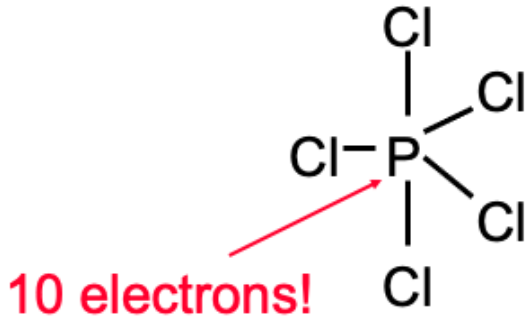
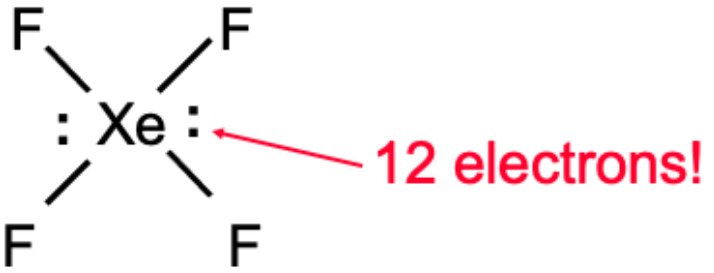
How many electrons does sulfur have in its valence shell?

Other examples – atoms with expanded valence shells





Hints on Lewis Dot Structures

1. Octet rule is the most useful guideline.
2. Carbon forms 4 bonds.
3. Hydrogen typically forms one bond to other atoms.
4. If multiple bonds are present, they usually involve C, N, O or S.
5. Nonmetals can form single, double, and triple bonds, but not quadruple bonds.
6. Always account for single bonds and lone pairs before forming multiple bonds.
7. Look for resonance structures.