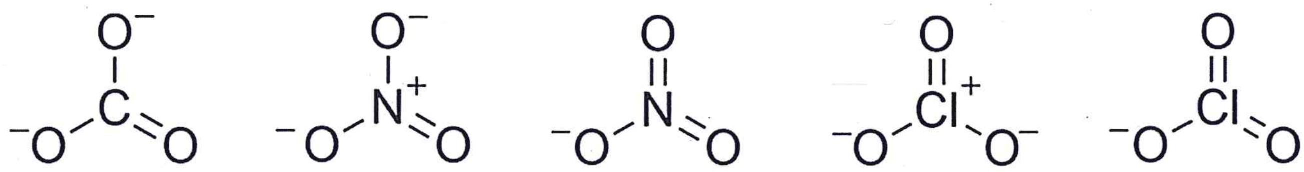
1. The following Lewis structures are shown without non-bonding electrons, but with their formal charges. Which of the following Lewis structures is invalid? That is, which one cannot be a valid Lewis/resonance structure in a description of the bonding in that species?



A B C D E

The easiest approach is to see if any n=2 elements violate the octet rule.

clearly C does ∵ N has 10 ē around itself.

Note: E has Cl with 10 ē around itself but Cl is in the n=3 period

$\boxed{\text{ANSWER} \equiv C}$

2. Which **ONE** of the following molecules obeys the octet rule for all atoms?

A. PF_5 B. BH_3 C. NO D. XeF_2 E. SiE

A is wrong $\because$ 5 F_s $\Rightarrow$ P has 10 $\bar{e}$s around itself

B is wrong $\because$ 3 H_s $\Rightarrow$ B has 6 $\bar{e}$s around itself.

C is wrong $\because$ NO has 11 valence electrons $\Rightarrow$ it is a radical. The Lewis structure with minimum formal charges $\equiv$ $\cdot\dot{N}=\ddot{O}$

N does not have an octet.

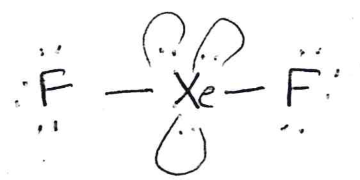
D is wrong : # valence electron $\equiv$ 8 + 2×7 = 22$\bar{e}$

− 4 for σ bonds

18

−12 (lone pairs on Fs)

6



5 electron domains ; linear molecule, 10 $\bar{e}$s around Xe.

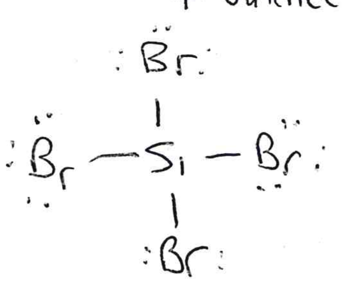
E is OK. # valence electrons = 4 + 7×4 = 32$\bar{e}$s

−8 σ bonds

24

− 24 (lone pairs on Brs)

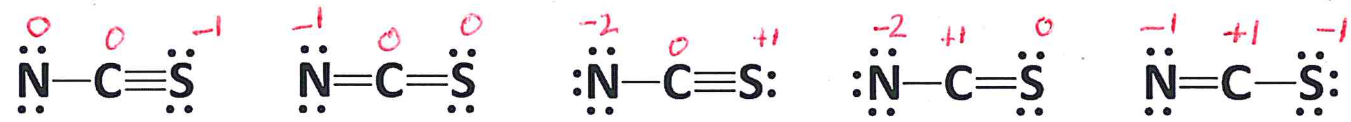
0



$\Rightarrow$ 8 $\bar{e}$s around Si

$\therefore$ ANSWER $\equiv$ E

3. Which one of the following resonance structures of NCS^- is most important in describing the bonding in the real molecule?



A B C D E

Most important resonance structure is the one with the minimum formal charges. (Nos in red above).

On this basis C, D, E are out.

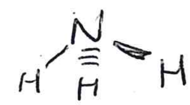
The deciding factor is therefore which element (N or S) is the most electronegative. N is more electronegative than S.

∴ ANSWER ≡ B

4. Calculate the overall change in energy (*i.e.* change in enthalpy, change in heat, ΔH_{rxn} in kJ mol^{-1}) for the reaction N_2 (g) + $3H_2$ (g) $\rightarrow$ $2NH_3$ (g).

A. -87 B. 87 C. 1077 D. 1209 E. -869

$$\Delta H_{rxn} = \sum D(\text{bonds broken}) - \sum D(\text{bonds formed}).$$

$N \equiv N + 3\ H-H \longrightarrow 2$ 

$$\therefore \Delta H_{rxn} = D(N \equiv N) + 3D(H-H) - 2 \times [3D(N-H)]$$

From data sheet

$$\Delta H_{rxn}\ (kJ\,mol^{-1}) = 945 + 3 \times 432 - 6 \times 388$$

$$= 945 + 1296 - 2328$$

$$= -87\ kJ\,mol^{-1}.$$

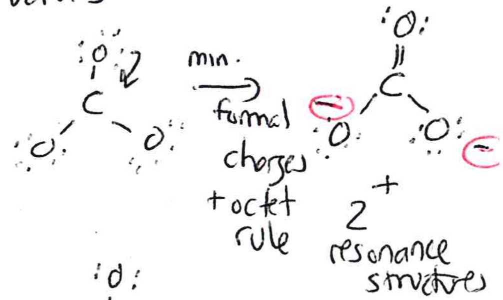
$\therefore$ ANSWER = A

5. Which of the following ions does NOT exhibit any bond orders greater than 1?

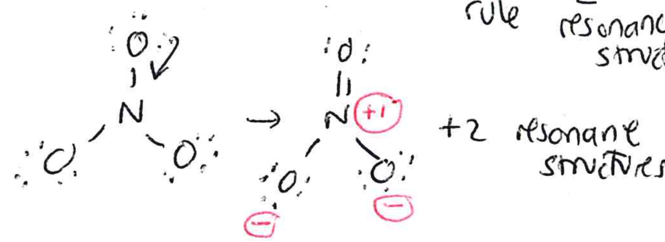
A. CO_3^{2-} B. NO_3^- C. OCN^- D. BF_4^- E. HCO_2^-

By inspection and experience know most bonds with F are single bonds. Still let's look a Lewis structures:

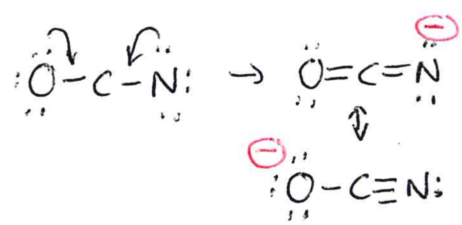
CO_3^{2-} # valence $\bar{e}$ = $4 + (3 \times 6) + 2 = 24$, $- 6$, 18



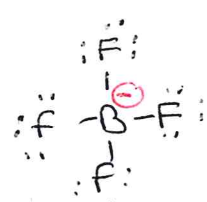
NO_3^- # valence $\bar{e}$ = $5 + (3 \times 6) + 1 = 24$, $- 6$, 18



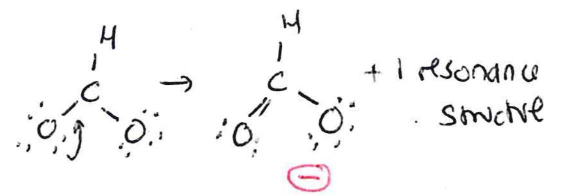
OCN^- # valence $\bar{e}$ = $6 + 4 + 5 + 1 = 16$, $- 4$, 12



BF_4^- # valence $\bar{e}$ = $3 + (7 \times 4) + 1 = 32$, $- 8$, 24, $- 24$, 0



HCO_2^- # valence $\bar{e}$ = $1 + 4 + (2 \times 6) + 1 = 18$, $- 6$, 12, $- 12$, 0



Only D does NOT exhibit a bond order > 1

∴ ANSWER ≡ D

7. Predict the shape of the XeO_4 molecule.

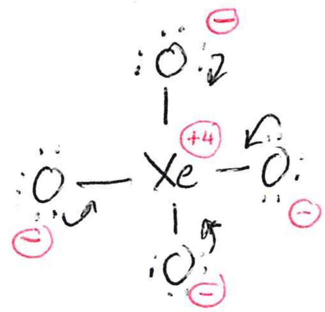
A. trigonal planar B. tetrahedral C. trigonal bipyramidal D. see saw E. square planar

Draw Lewis structure.

valence electrons $= 8 + 4 \times 6 = 32\,e^-$

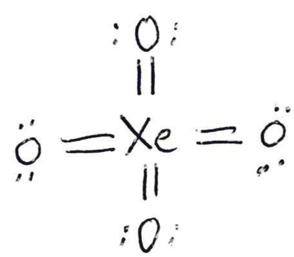
$- 8$ (σ bonds)

24



Minimize formal charges; octets around Os.

(all formal charges are $\emptyset$).



$4\ e^-$ domains $\Rightarrow$ tetrahedral

$\therefore$ ANSWER $\equiv$ B

8. Which element M will lead to an MF_4 molecule with square planar molecular geometry?

	A. Xe	B. Ga	C. Sn	D. Se	E. Si
# valence $\bar{e}$	8	3	4	6	4.

Square Planar requires 6 electron domains (Octahedral)
but only 4 atoms bonded to central atom.

$\Rightarrow$ only Xe can do this.

ANSWER $\equiv$ A

Long answer is to work out Lewis structures and
see which element allows 6 $\bar{e}$ domains.

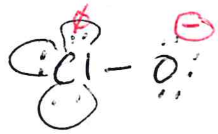
9. Which of the following anions has **ONLY ONE** non-bonded pair of electrons (lone pair) on the **chlorine**?

A. Cl^- B. ClO^- C. ClO_2^- D. ClO_3^- E. ClO_4^-

Cl^- $\xrightarrow[\bar{e}]{8 \text{ valance}}$:Cl: (4 lone pairs).

ClO^- # valence $\bar{e}$ = 7 + 6 + 1 = 14

$$\begin{array}{r} 14 \\ -2 \\ \hline 12 \\ -12 \\ \hline 0 \end{array}$$



(3 lone pairs)

ClO_2^- # valence $\bar{e}$ = 7 + (2×6) + 1 = 20

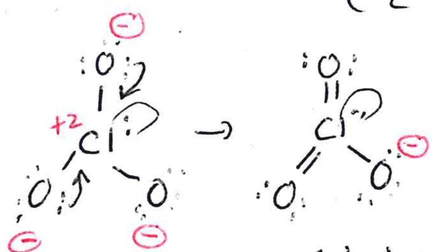
$$\begin{array}{r} 20 \\ -4 \\ \hline 16 \\ -16 \\ \hline 0 \end{array}$$

+ 1 resonance structure

(2 lone pairs).

ClO_3^- # valence $\bar{e}$ = 7 + (3×6) + 1 = 26

$$\begin{array}{r} 26 \\ -6 \\ \hline 20 \\ -18 \\ \hline 2 \end{array}$$

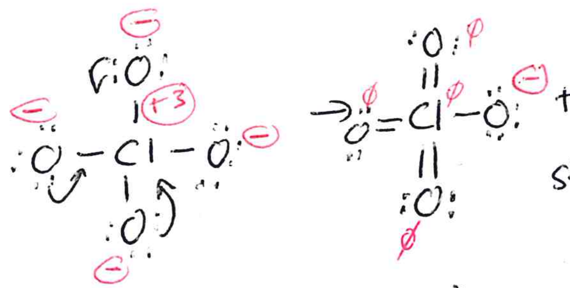


+ 2 resonance structures

(1 lone pair)

ClO_4^- # valence $\bar{e}$ = 7× (4×6) + 1 = 32

$$\begin{array}{r} 32 \\ -8 \\ \hline 24 \\ -24 \\ \hline 0 \end{array}$$

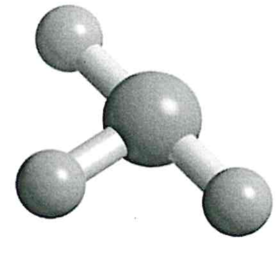


+ 3 resonance structures

(no lone pairs)

ANSWER = D

10. The structure shown is a representation of which molecule?

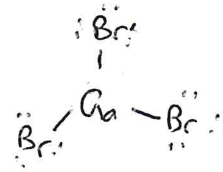


A. $GaBr_3$ B. PCl_3 C. BF_3 D. AsH_3 E. IF_3

Could recall that T-shape molecules come from 5 electron domain system. On that basis E ≡ answer by default.

Work through Lewis structures

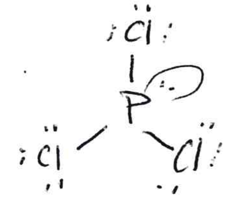
$GaBr_3$: # valence $\bar{e}$ = $3 + 7\times3 = 24$
$- 6$
18



; 3 $\bar{e}$ domains trigonal planar.

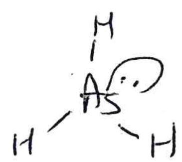
BF_3 is the same type of molecule ∵ # valence $\bar{e}$ = $3 + (7\times3) = 24$.

PCl_3: # valence $\bar{e}$ = $5 + 7\times3 = 26$
-6
20
-18
2



; 4 $\bar{e}$ domains tetrahedral. molecule = trigonal pyramidal

AsH_3: # valence $\bar{e}$ = $5 + 3 = 8$
-6
2



; 4 $\bar{e}$ domains tetrahedral molecule is trigonal pyramidal

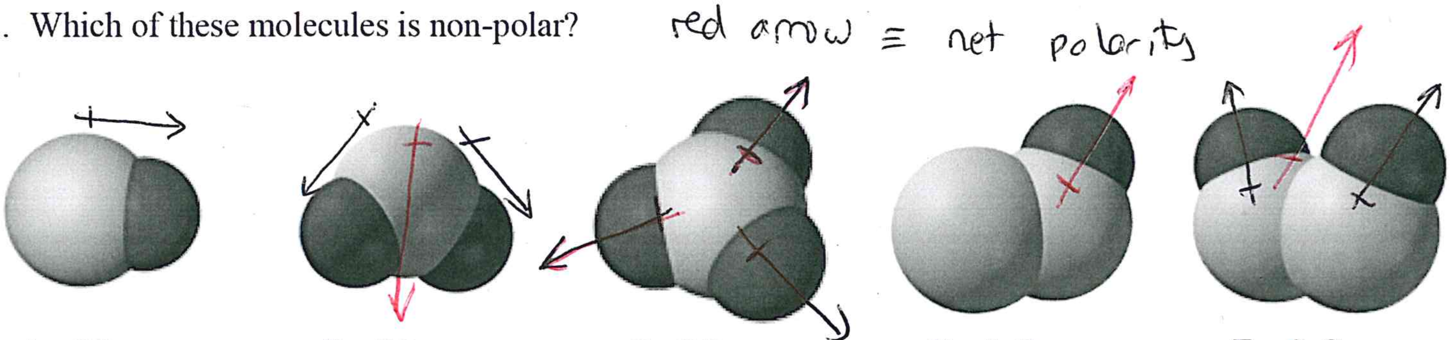
IF_3: # valence $\bar{e}$ = $7\times4 = 28$
-6
22
-18
4

; 5 $\bar{e}$ domains trigonal bipyramidal molecule is T-shape.

ANSWER ≡ E

11. Which of these molecules is non-polar?

red arrow ≡ net polarity



A. SO

Polar

B. SO_2

polar

C. SO_3

non-polar

D. S_2O

Polar

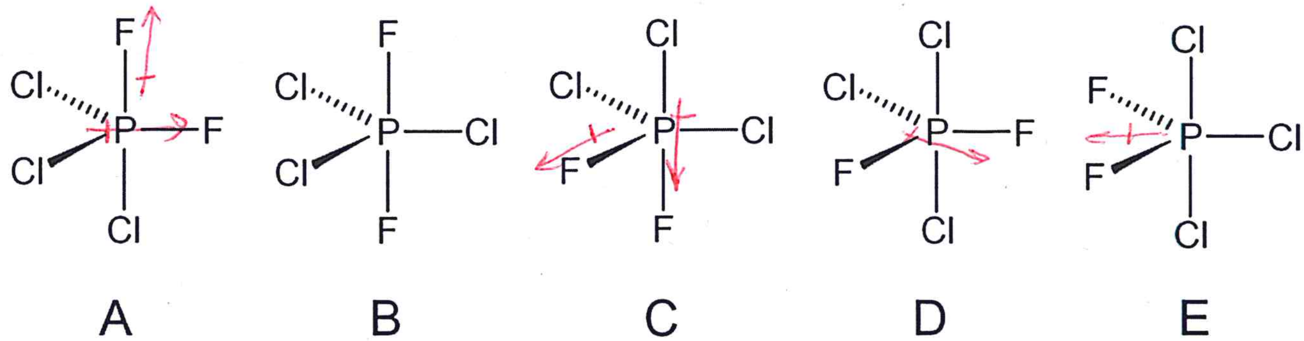
E. S_2O_2

polar

Should be able to do this by inspection.

ANSWER ≡ C

12. Which of the trigonal bipyramidal PCl_3F_2 structures below is non-polar?

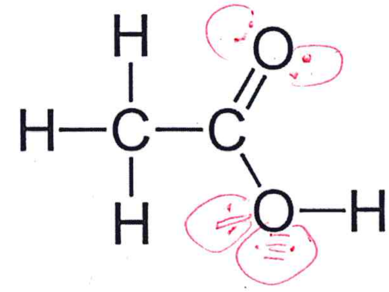


red arrows show ~ net polarity in axial and equitorial directions

only B is non-polar in both the axial and equitorial directions by inspection

ANSWER ≡ B

Questions 13-19 concern the molecule acetic acid, $C_2H_4O_2$ (structure shown at the right). Lone pairs are not shown.



Carbon, oxygen obey octet rule $\Rightarrow$ can put in lone pairs (shown in red)

13. How many non-bonding valence electrons are there in a molecule of acetic acid?

A. 0 B. 2 C. 4 D. 6 E. 8

4 lone pairs $\Rightarrow$ 8 non-bonding electrons

$\therefore$ ANSWER = E

14. The O-C-O and C-O-H bond angles in a molecule of acetic acid are closest to what pair of values, respectively?

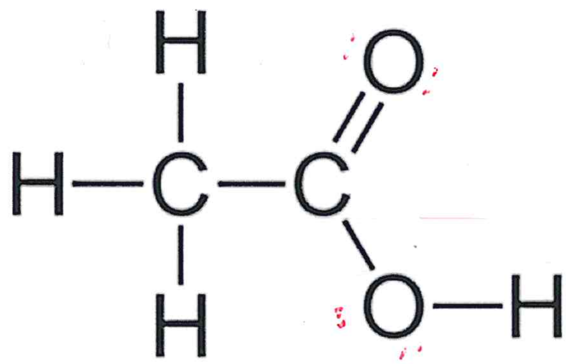
A. 120°, 109.5°

B. 120°, 120°

C. 109.5°, 120°

D. 109.5°, 109.5°

E. 120°, 90°



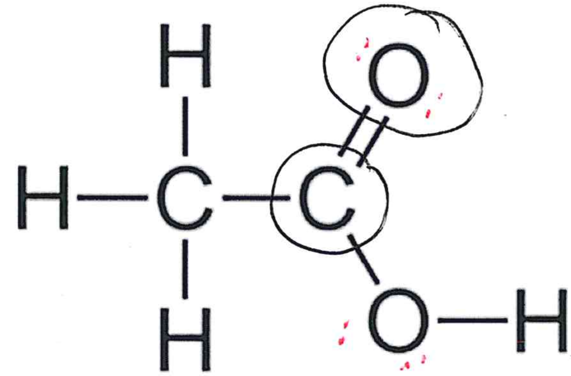
O-C-O involves 3 $\bar{e}$ domains ⇒ trigonal planar ⇒ ≈ 120°

C-O-H involves 4 $\bar{e}$ domains; 2 σ bonds and 2 pairs of non-bonding $\bar{e}$s. ⇒ tetrahedral ⇒ ~ 109.5°

∴ ANSWER ≡ A

15. How many sp^2 hybrid orbitals are there in a molecule of acetic acid?

A. 1 B. 2 C. 3 D. 4 E. 6



I've circled the elements with 3 electron domains

on C ; 2σ bonds + $(1\sigma + 1\pi)$ double bond.

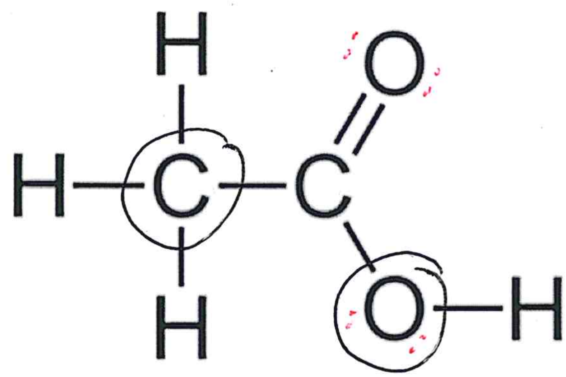
on O , 1 double bond + 2 lone pairs.

$\therefore$ # sp^2 orbitals $\equiv \underset{\substack{\uparrow \\ \text{on C}}}{3} + \underset{\substack{\uparrow \\ \text{on O}}}{3} = 6$

ANSWER $\equiv$ E

16. How many sp^3 hybrid orbitals are there in a molecule of acetic acid?

A. 2 B. 4 C. 6 D. 8 E. 16



I've circled the atoms with 4 electron domains

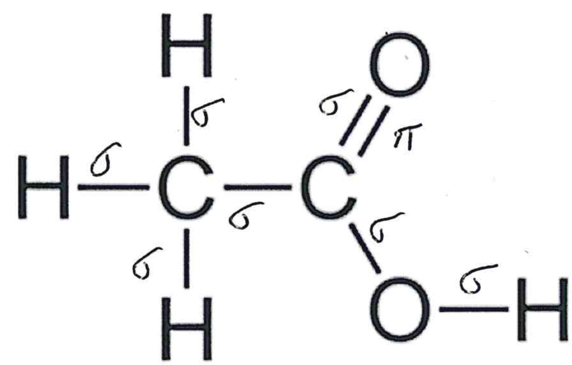
C : 4 σ bonds

O : 2 σ bond + 2 lone pairs.

∴ # sp^3 hybrid orbitals = $\underset{\text{on C}}{4} + \underset{\text{on O}}{4} = 8$

17. A molecule of acetic acid has how many sigma (σ) and how many pi (π) bonds?

A. 5 σ, 1 π B. 6 σ, 1 π C. 6 σ, 2 π D. 7 σ, 1 π E. 7 σ, 2 π



Remember a double bond is a $\sigma + \pi$ bonds

∴ # σ bonds = 7

π bonds = 1

∴ ANSWER = D