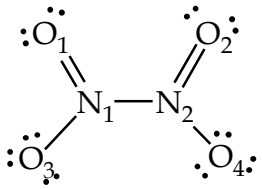
Name: _____ Date:_____

Homework 7 – Lewis structures and resonance

1.) Draw 4 resonance structures for N_2O_4 (no O-O bonds, there IS a bond between N-N): use formal charge calculations to determine the "best" resonance structure(s)

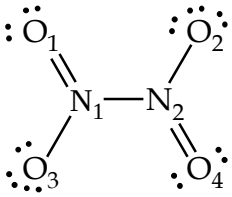
Valence electrons: N: 2 x 5 = 10 O: 4 x 6 = 24 10+ 24 = **34 valence electrons**

I



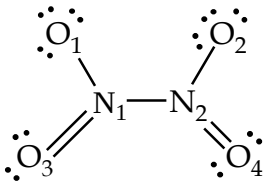
Formal Charges
N_1: 5 - 4 = +1
N_2: 5 – 4 = +1
O_1: 6 – 6 = 0
O_2: 6 – 6 = 0
O_3: 6 – 7 = -1
O_4: 6 – 7 = -1

II



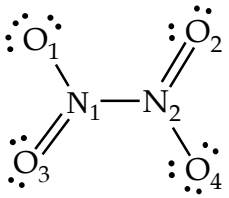
Formal Charges
N_1: 5 – 4 = +1
N_2: 5 – 4 = +1
O_1: 6 – 6 = 0
O_2: 6 – 7 = -1
O_3: 6 – 7 = -1
O_4: 6 – 6 = 0

III



Formal Charges
N_1: 5 – 4 = +1
N_2: 5 – 4 = +1
O_1: 6 – 7 = -1
O_2: 6 – 7 = -1
O_3: 6 – 6 = 0
O_4: 6 – 6 = 0

IV



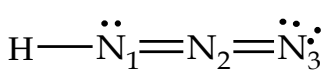
Formal Charges
N_1: 5 – 4 = +1
N_2: 5 – 4 = +1
O_1: 6 – 7 = -1
O_2: 6 – 6 = 0
O_3: 6 – 6 = 0
O_4: 6 – 7 = -1

All structures contribute equally – all have two Nitrogens at +1, two oxygens at -1, and 2 oxygens at 0. No structure is better than another: molecular shape: trigonal planar VSEPR: trigonal planar, hybridization: sp^2, angle: 120^o

2.) Draw 3 resonance structures for HN_3 (NOT NH_3!!!!) – (skeletal H-N-N-N) use formal charge calculations to determine the "best" resonance structure(s) – model your set-up as question 1 is displayed

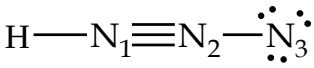
N: 3 x 5 = 15 H: 1 x 1 = 1 15 + 1 = **16 valence electrons**

I



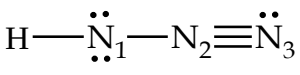
H: 1 -1 = 0
N_1: 5 – 5 = 0
N_2: 5 – 4 = +1
N_3: 5 – 6 = -1

II



H: 1 – 1 =0
N_1: 5 – 4 = +1
N_2: 5 – 4 = +1
N_3: 5 – 7 = -2

III



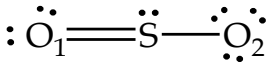
H: 1 – 1 = 0
N_1: 5 – 6 = -1
N_2: 5 – 4 = +1
N_3: 5 – 5 = 0

Structures I and III are equivalent and are better than structure II: Molecular shape: linear, VSEPR: linear, hybridization: sp , angle: 180^o

3.) Draw 3 resonance structures for SO_2 (no O-O bonds) – use formal charges to determine the "best" structure(s) – model your set-up as question 1 is displayed

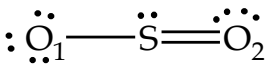
S: 1 x 6 = 6 O: 2 x 6 = 12 6 + 12 = **18 valence electrons**

I



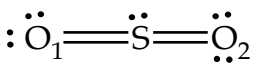
S: 6 – 5 = +1
O_1: 6 – 6 = 0
O_2: 6 – 7 = -1

II



S: 6 – 5 = +1
O_1: 6 – 7 = -1
O_2: 6 – 6 = 0

III



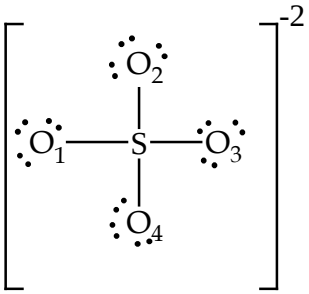
S: 6 – 6 = 0
O_1: 6 – 6 = 0
O_2: 6 – 6 = 0

Structure 3 is the best structure – all formal charge values are zero! Molecular shape: bent, VSEPR: trigonal planar, hybridization: sp^2 angle: 120^o

4.) For SO_4^{-2} draw at least 3 resonance structures – one of which MUST be the "best" structure for the ion (which means minimize the formal charge value on the central atom)! (hint: make your structure symmetrical)- use formal charge calculations to determine which ion is the "best" resonance structure – model your set-up as question 1 is displayed.

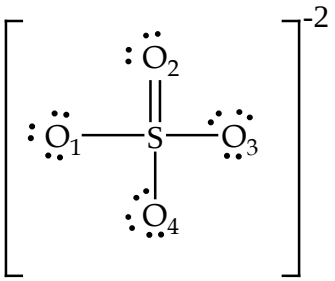
Valence: S: 6 x 1 = 6 O: 4 x 6 = 24 6 +24 = 30 + 2 = **32 valence electrons**

I



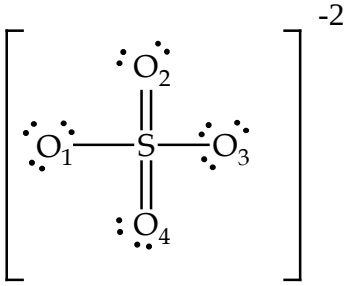
S: 6 – 4 = +2
O_1: 6 – 7 = -1
O_2: 6 – 7 = -1
O_3: 6 – 7 = -1
O_4: 6 – 7 = -1

II



S: 6 – 5 = +1
O_1: 6 – 7 = -1
O_2: 6 – 6 = 0
O_3: 6 – 7 = -1
O_4: 6 – 7 = -1

III



S: 6 – 6 = 0
O_1: 6 – 7 = -1
O_2: 6 – 6 = 0
O_3: 6 – 7 = -1
O_4: 6 – 6 = 0

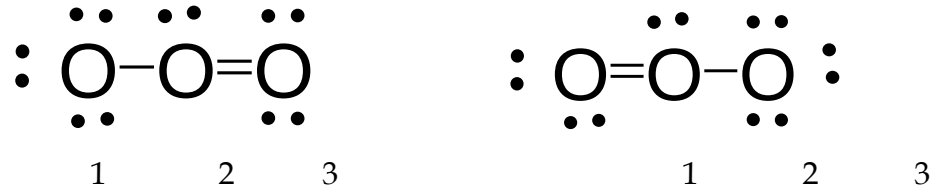
The best structure is structure III – central atom is minimized (formal charge = 0) and two oxygens have 0 formal charge values and only 2 have -1 formal charge values.

There are 3 additional resonance structures based on structure II, where the double bond rotates around the structure

There are 4 additional resonance structures for structure III where there are two sets of double bonds that rotate around the structure

5.) Draw 2 resonance structures for O_3 (skeletal structure is O - O – O it is not a ring!) use formal charge calculations to determine which ion is the "best" resonance structure – model your set-up as question 1 is displayed

O: 6 valence x 3 oxygens = 18 total valence electrons



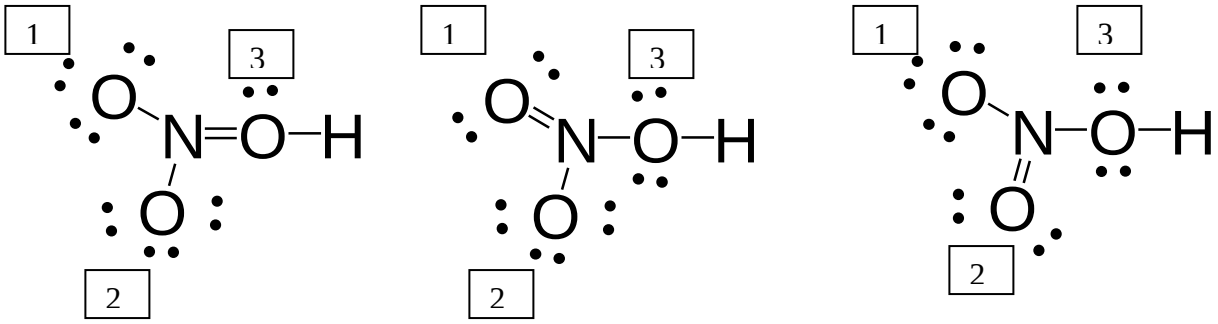
O_1 : 6-7 = -1
O_2 : 6-5 = +1
O_3 : 6-6 = 0

O_1 : 6-6 =0
O_2 : 6-5 = +1
O_3 : 6 -7 = -1

Neither structure is better than the other. Both have a zero formal charge Oxygen, a -1 formal charge oxygen, and a +1 formal charge oxygen. Since neither structure is better , they contribute equally to the overall resonance hybrid: molecular: bent, VSEPR: trigonal planar, hybridization is sp^2, angle is 120^o

6.) Draw 3 resonance structures for HNO_3 (H bonded to O, no O-O bonds) use formal charge calculations to determine which ion is the "best" resonance structure – model your set-up as question 1 is displayed

Valence e^{-1} = 5 valence nitrogen + 1 valence hydrogen + (6 valence oxygen x 3) = 24 valence electrons



STRUCTURE 1

N : 5 – 4 = +1
O_1 : 6 – 7 = -1
O_2 : 6 – 7 = -1
O_3 : 6 – 5 = + 1
H : 1 – 1 = 0

STRUCTURE 2

N : 5 – 4 = +1
O_1 : 6 – 6 = 0
O_2 : 6 – 7 = -1
O_3 : 6 – 6 = 0
H : 1 – 1 = 0

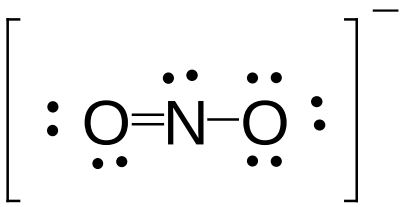
STRUCTURE 3

N : 5 – 4 = +1
O_1 : 6 – 7 = -1
O_2 : 6 – 6 = 0
O_3 : 6 – 6 = 0
H : 1 – 1 = 0

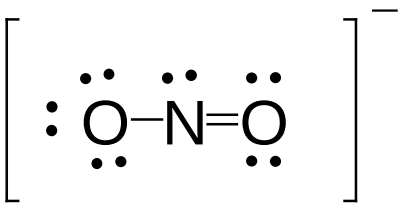
The first structure has 2 species at a +1 formal charge and 2 species at a -1 formal charge. Structures 2 and 3 only have 1 species at a +1 formal charge and 1 species at a -1 formal charge. The rest of the atoms are at a zero formal charge. This means that structures 2 and 3 are better than structure 1. BUT, there is again, no difference between structures 2 and 3. They are equal to one another (the nitrogen is the least electronegative atom and it carries the +1 formal charge value while the oxygen, which is more electronegative carries the -1 formal charge value). Therefore, structures 2 and 3 contribute equally to the overall resonance hybrid: molecular shape is trigonal planar, VSEPR is trigonal planar, angle is 120°, hybridization is sp^2

7.) Draw 2 resonance structures for $[NO_2]^{-1}$ use formal charge calculations to determine which ion is the "best" resonance structure – model your set-up as question 1 is displayed

N = 5 valence + (6 valence x 2 oxygens) + $1e^{-1}$ = 18 total valence electrons



1 2



1 2

O_1 : 6-6 = 0
N : 5-5 = 0
O_2 : 6-7 = -1

O_1 : 6-7 = -1
N : 5-5 = 0
O_2 : 6 -6 = 0

Neither structure is better than the other. Both have a zero formal charge Oxygen, a -1 formal charge oxygen, and a +1 formal charge nitrogen. Since neither structure is better , they contribute equally to the overall resonance hybrid: molecular shape is bent, VSEPR is trigonal planar, hybridization is sp^2, angle is 120°