

CH 222 Friday January 19, 2018 L08

Good Afternoon

“These are not the bonds you’re looking for:
Introduction to Resonance Structures”

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Obi-Wan Kanobi
Mos Eisley, Tatooine



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As bond order increases, bond length _____.

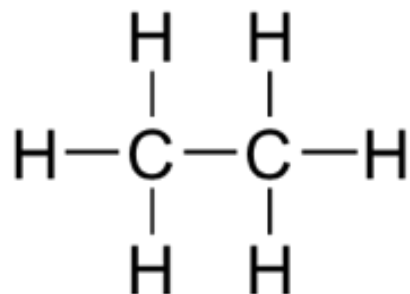
Therefore, bond energy _____.

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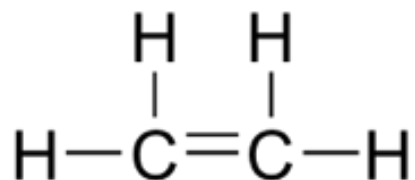
Table 9.3 The Relation of Bond Order, Bond Length, and Bond Energy

Bond	Bond Order	Average Bond Length (pm)	Average Bond Energy (kJ/mol)
C—O	1	143	358
C=O	2	123	745
C≡O	3	113	1070
C—C	1	154	347
C=C	2	134	614
C≡C	3	121	839
N—N	1	146	160
N=N	2	122	418
N≡N	3	110	945

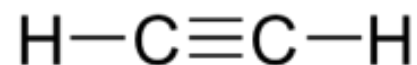
Double and triple bonds are quite common,
and not just something we do on paper.



ethane
(an **alkane**)



ethene
(an **alkene**)



ethyne
(an **alkyne**)

As bond order increases, bond length _____.

Therefore, bond energy _____.

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N=N	2	122	418
N≡N	3	110	945

Ozone, O₃: average bond energy = 364 kJ/mol

Calculate the energy **per molecule**.

$$364 \text{ kJ} / \text{mol} \left(\frac{1 \text{ mol}}{6.022 \times 10^{23}} \right) = 6.04 \times 10^{-19} \text{ J} / \text{molecule}$$

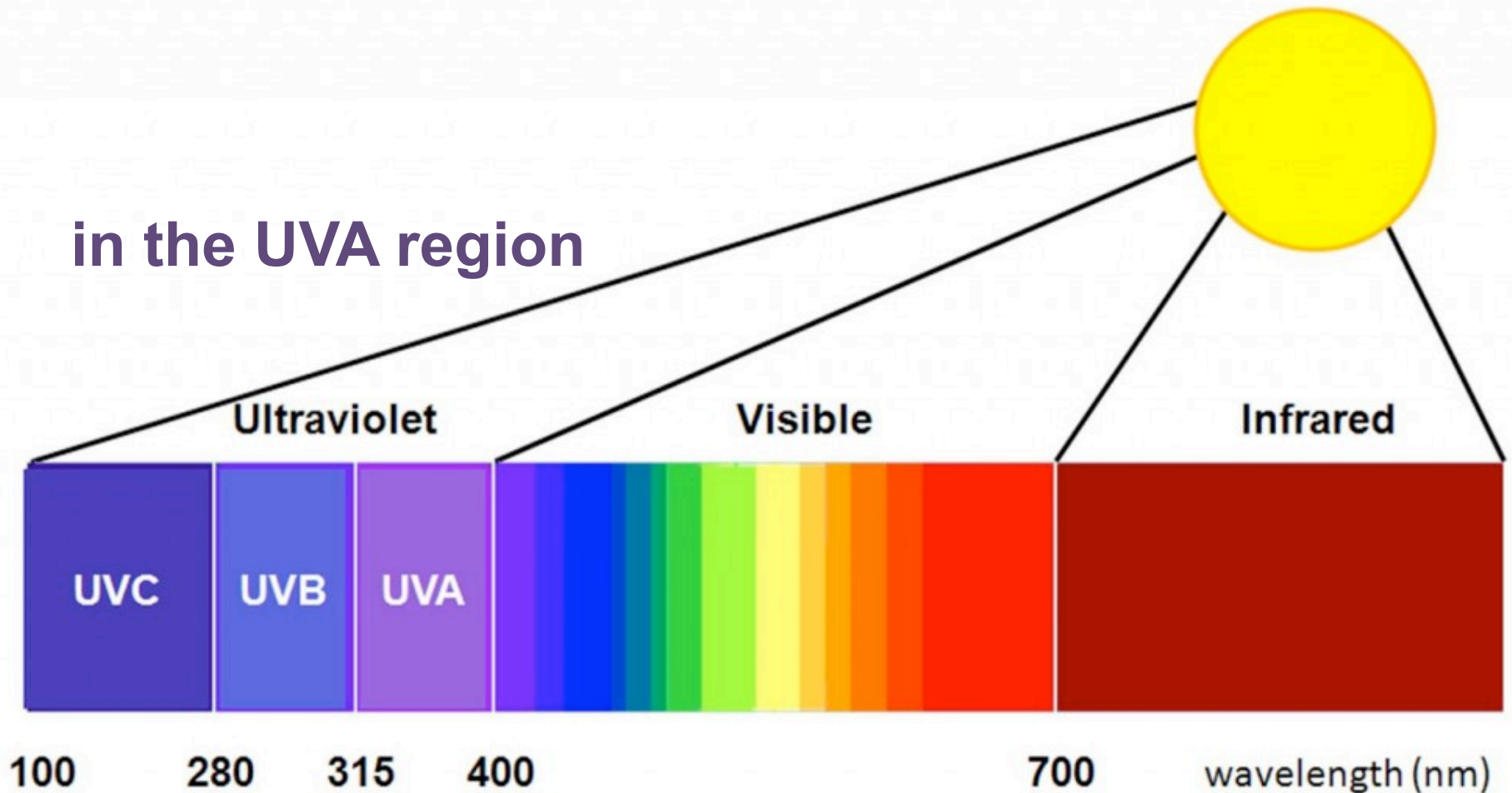
Calculate the wavelength of light that would be necessary to break the bonds in O₃.

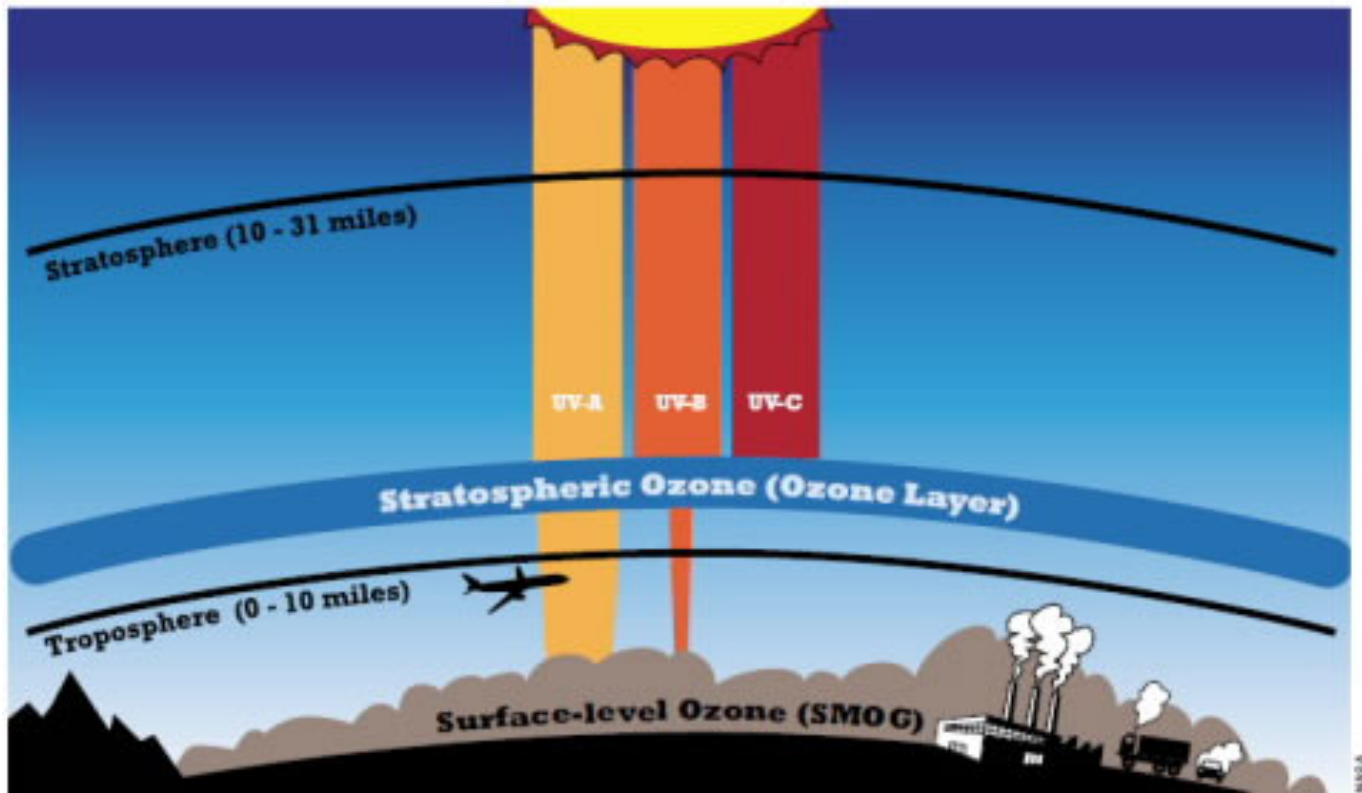
$$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \quad c = 3.00 \times 10^8 \text{ m/s}$$

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J} \cdot \text{s})(3.00 \times 10^8)}{6.04 \times 10^{-19} \text{ J}} = 3.28 \times 10^{-7} \text{ m}$$
$$= 328 \text{ nm}$$

$\lambda = 328 \text{ nm}$ What part of the UV spectrum?

in the UVA region





UV-A = 400 – 320 nm

UV-B = 320 – 280 nm

UV-C = < 280 nm

When outdoors during the daylight hours, wear sunglasses that can block UV light, even on cloudy days. UV rays pass through clouds and will damage unprotected eyes.

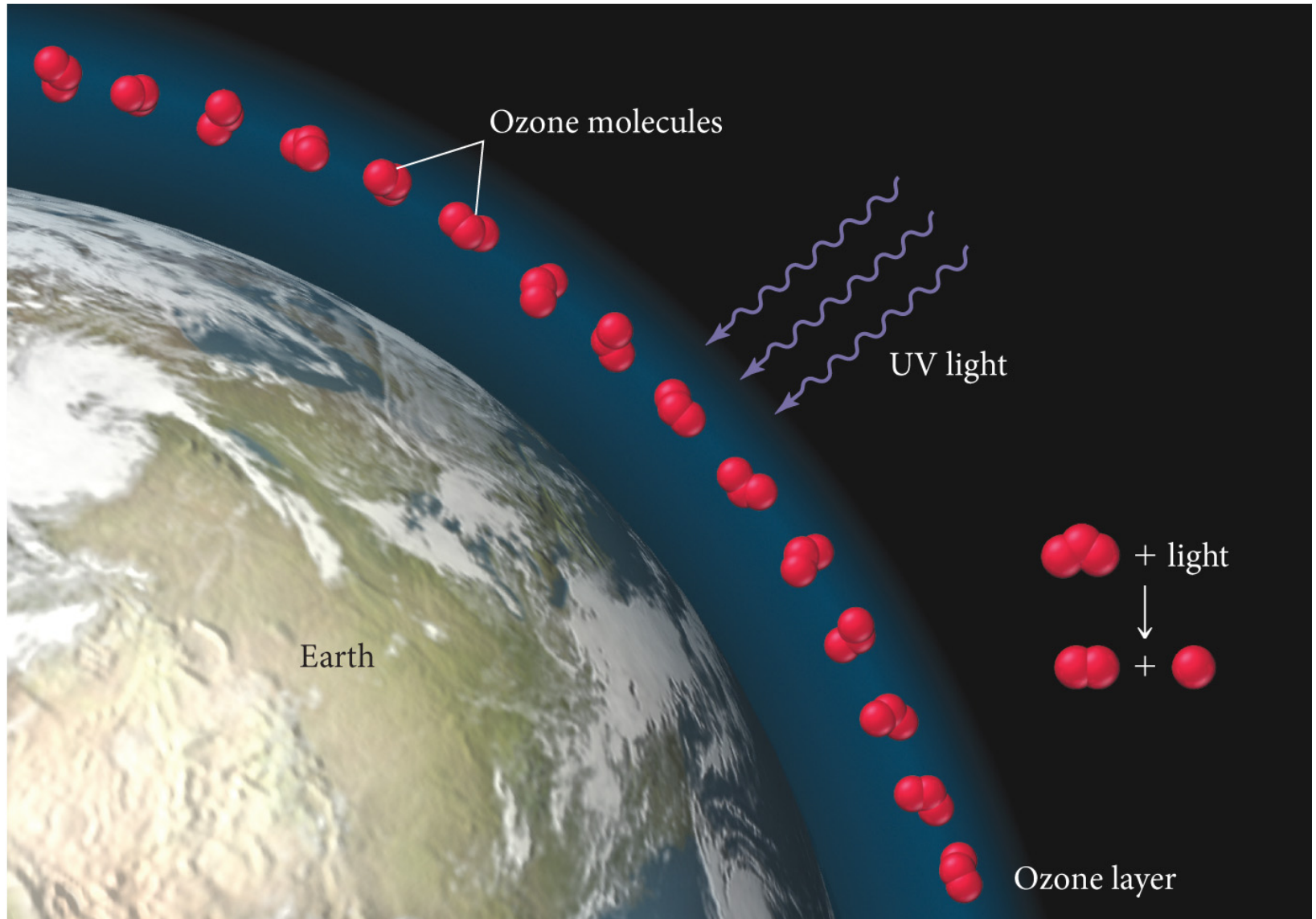
- > **Blue Light Filter**
 - > **UV Blocking**
 - > **Anti-Fatigue**
 - > **Gaming Goggles**
- Brightzone**



- > **Sleep Better**
- > **Stop Eye Strain**
- > **Protect Your Eyes**

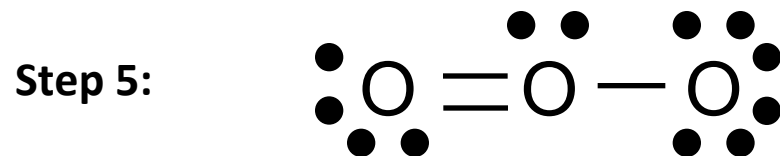
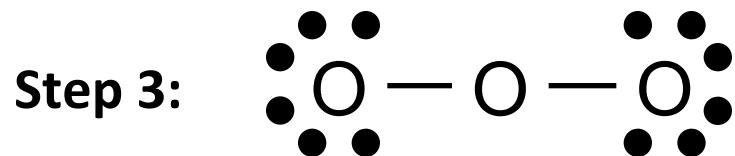
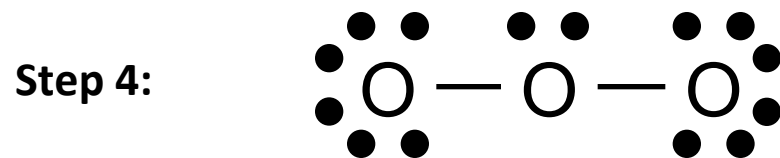
Improve your chemistry exam scores.

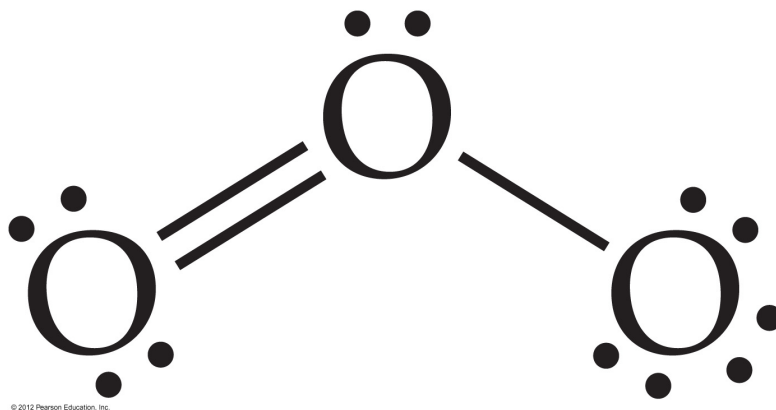
Draw the Lewis structure for ozone, O_3 .
All atoms must obey the Octet Rule.



Lewis Structures and Resonance

Step 1: $3(6) = 18$ valence electrons

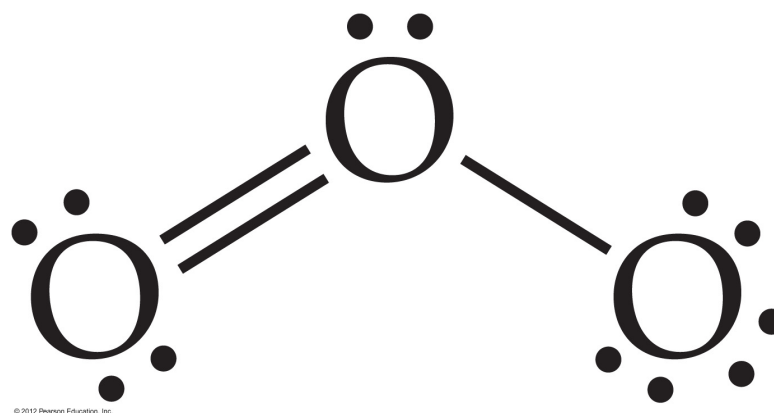




Correct Lewis structure for ozone, O₃?

Draw the Lewis Structure for O₃

This is the Lewis structure we would draw for ozone, O₃.



How many single bonds?

How many double bonds do you see?



Star Wars Episode VII and VIII
Kylo Ren his real name is

Obi-Wan Kenobi His real name is



Star Wars Episode IV A New Hope



Star Wars Episode IV A New Hope

Who is the lady and what is she giving R2D2?



Star Wars Episode IV A New Hope

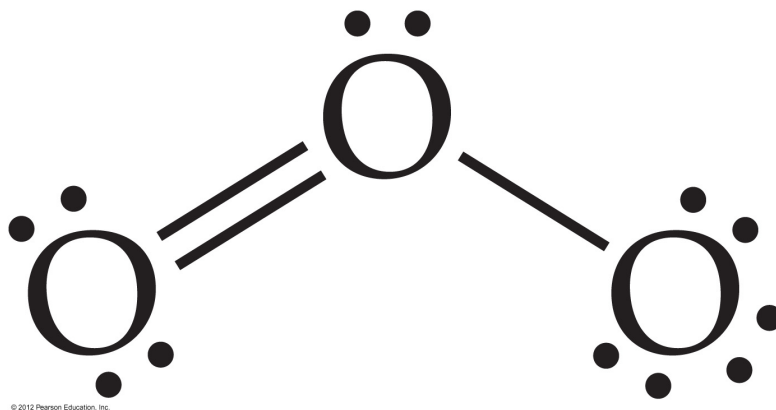
“General Kenobi. Years ago you served my father in the Clone Wars. Now he begs you to help him in his struggle against the Empire. I regret that I am unable to present my father's request to you in person, but my ship has fallen under attack, and I'm afraid my mission to bring you to Alderaan has failed. I have placed information vital to the survival of the Rebellion into the memory systems of this R2 unit. My father will know how to retrieve it. You must see this droid safely delivered to him on Alderaan. This is our most desperate hour. Help me, Obi-Wan Kenobi. You're my only hope.”



Star Wars Episode IV



<https://www.youtube.com/watch?v=532j-186xEQ>



Correct Lewis structure for ozone, O₃?

Bond Enthalpy and Bond Length

TABLE 8.5 • Average Bond Lengths for Some Single, Double, and Triple Bonds

Bond	Bond Length (Å)	Bond	Bond Length (Å)	
C—C	1.54	N—N	1.47	
C=C	1.34	N=N	1.24	
C≡C	1.20	N≡N	1.10	
C—N	1.43	N—O	1.36	
C=N	1.38	N=O	1.22	Bond Energy
C≡N	1.16			
C—O	1.43	O—O	1.48	204 kJ/mol
C=O	1.23	O=O	1.21	498 kJ/mol
C≡O	1.13			

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1.48

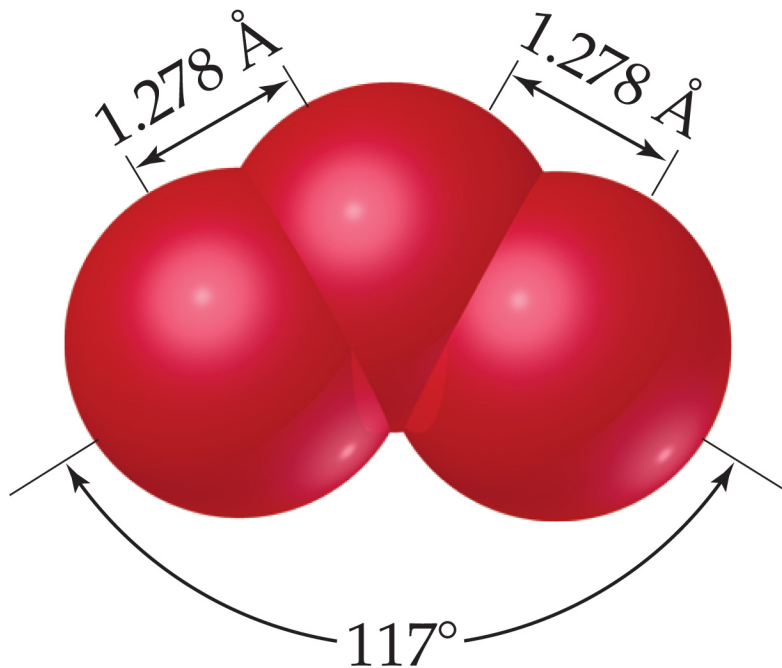
148 pm



1.21

121 pm

Bond Length and Bond Angle Measurements



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- But this is at odds with the true, observed structure of ozone,
- Both O-O bond lengths in O_3 are the same.

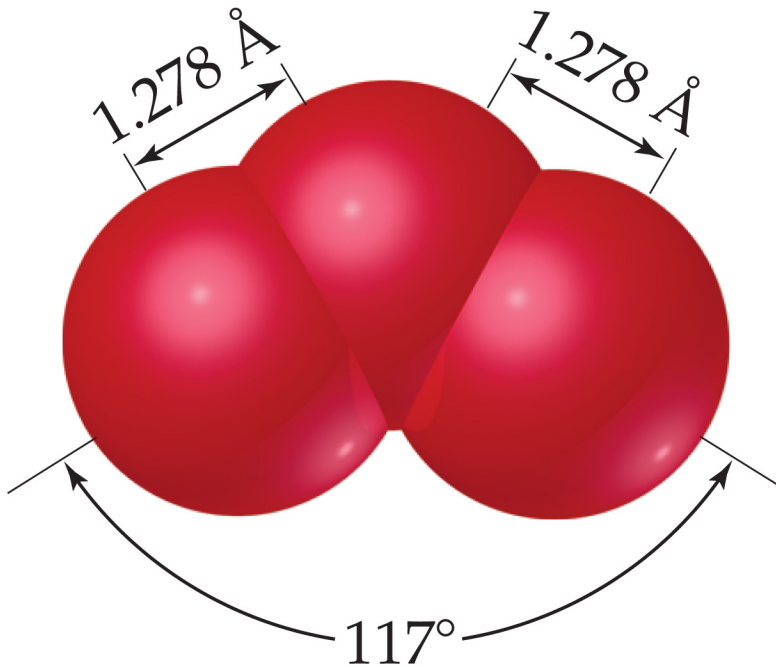


1.48



1.21

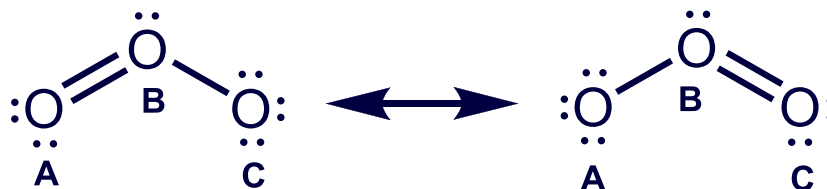
Ozone



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- But this is at odds with the true, observed structure of ozone, in which...
 - ...both O—O bonds have the same bond energy
 - ...both outer oxygens have a charge of $-1/2$.
 - O₃ does not have a single bond and it does not have a double bond.

What is the bond order in ozone?



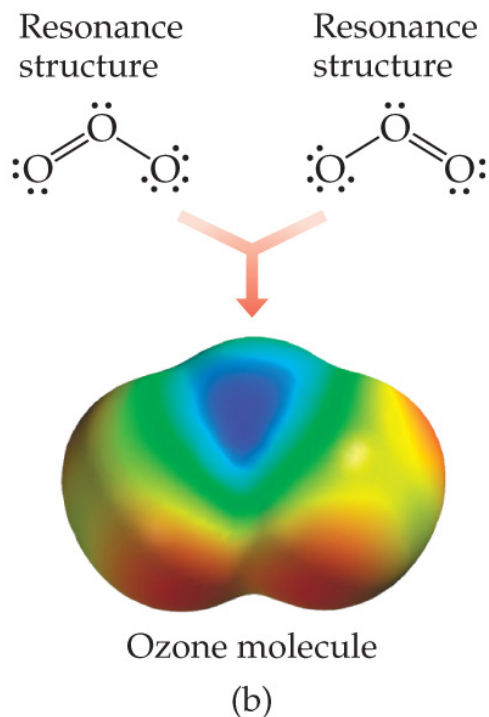
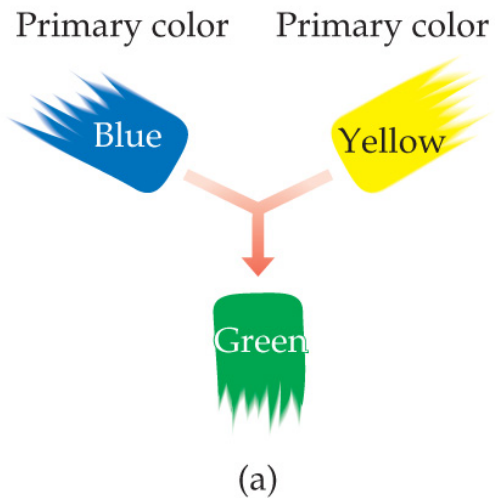
Bond order is somewhere intermediate between 1 and 2.

When equivalent Lewis structures can be drawn, the bond order is calculated as:

$$\text{bond order} = \frac{\text{number of bonding pairs}}{\text{number of bonding regions}} = \frac{3}{2} = 1.5$$

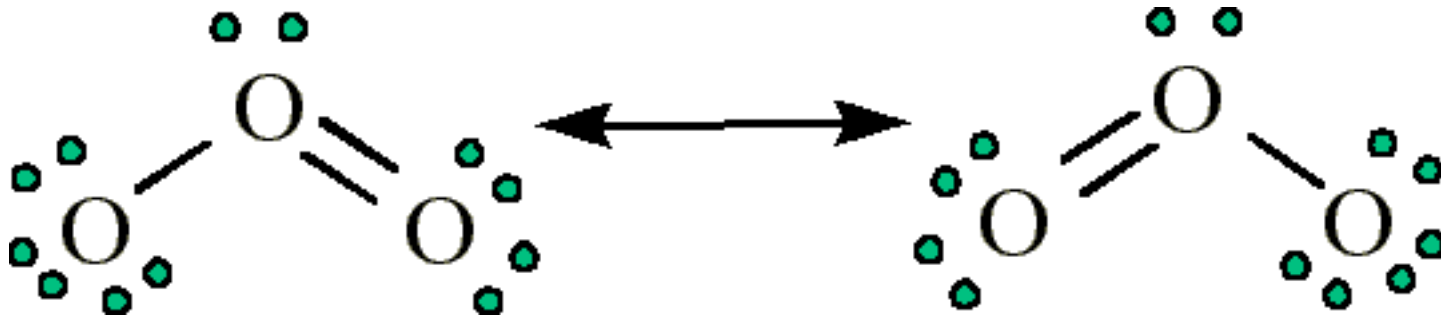
Resonance

Just as green is a synthesis of blue and yellow...



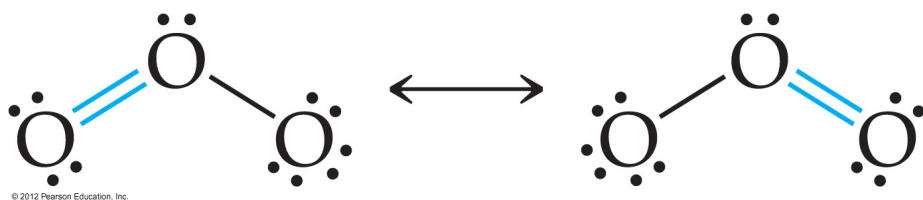
...ozone is a synthesis of these two resonance structures.

Draw the Lewis structure for O_3

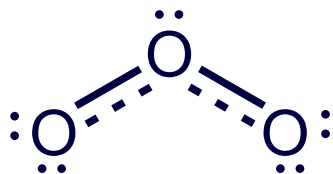


Resonance: Electron Delocalization

- When one Lewis structure cannot accurately depict a molecule like ozone. We use multiple structures, resonance structures, to describe the molecule.



In a resonance hybrid, electrons are ***delocalized***: their density is “spread” over a few adjacent atoms.

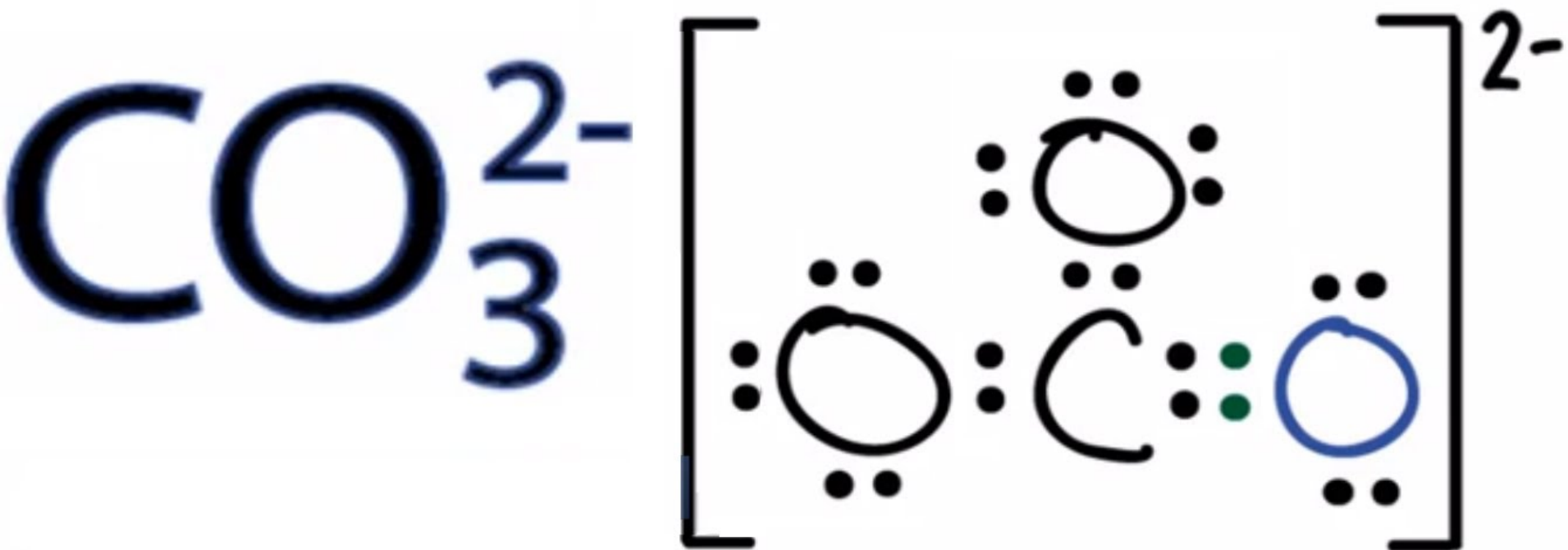


Extra stability is gained by having resonance structures.

Dotted lines are used to show delocalized electrons.

Draw the Lewis structure for
 CO_3^{2-}

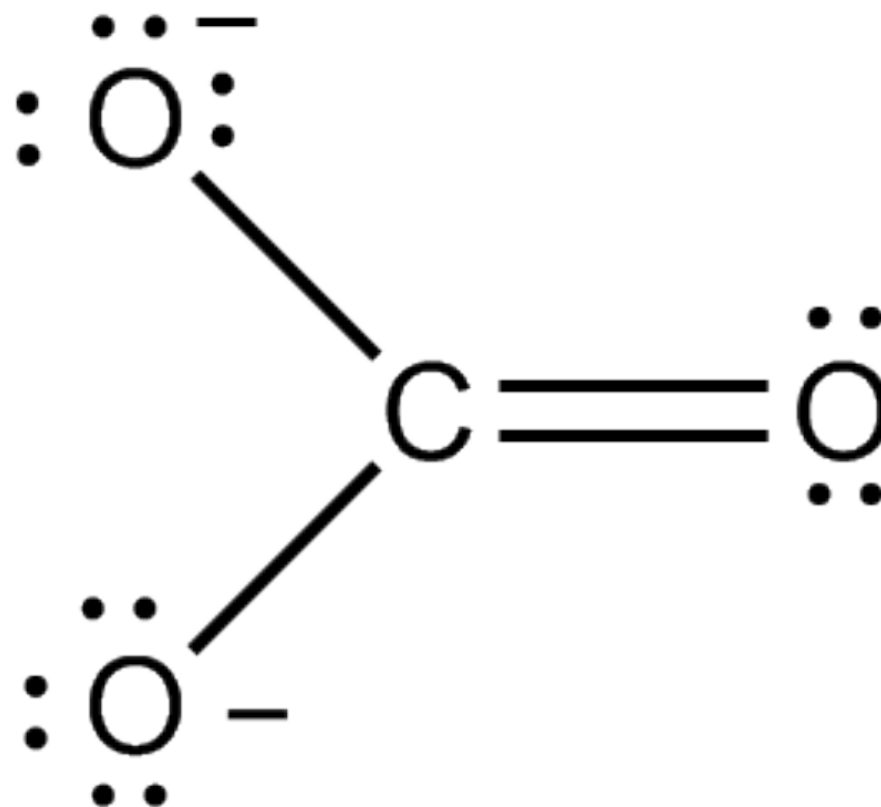
Draw the Lewis structure for CO_3^{2-}



Formal Charge	=	Valence Electrons	-	NonBonding Val Electrons	-	<u>Bonding Electrons</u>	=	
						$\frac{\quad}{2}$		
C	=	4	-	0	-	$\frac{8}{2}$	=	0
O	=	6	-	6	-	$\frac{2}{2}$	=	-1
		6	-	4	-	$\frac{4}{2}$	=	0

Draw the Lewis Structure for CO_3^{2-}

This is the Lewis structure we would draw for, CO_3^{2-}



How many single bonds?

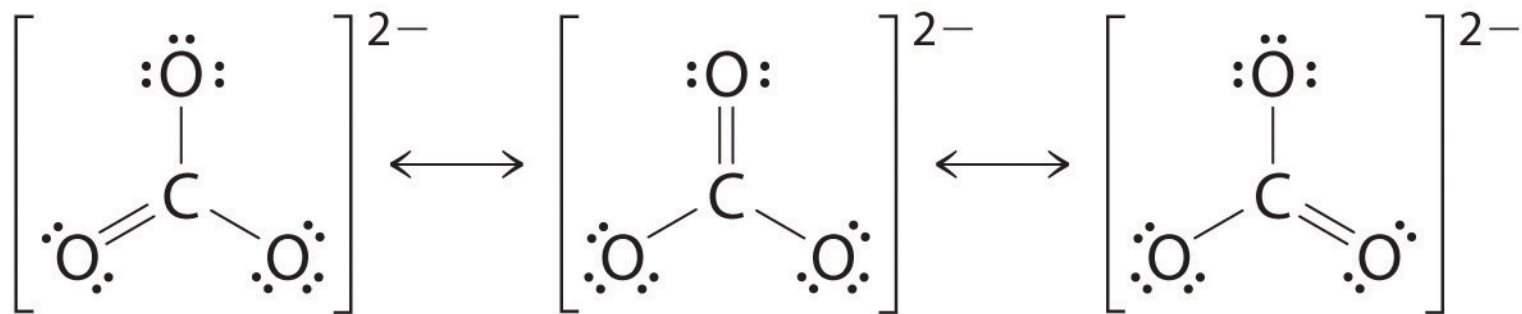
How many double bonds do you see?

Carbonate ion

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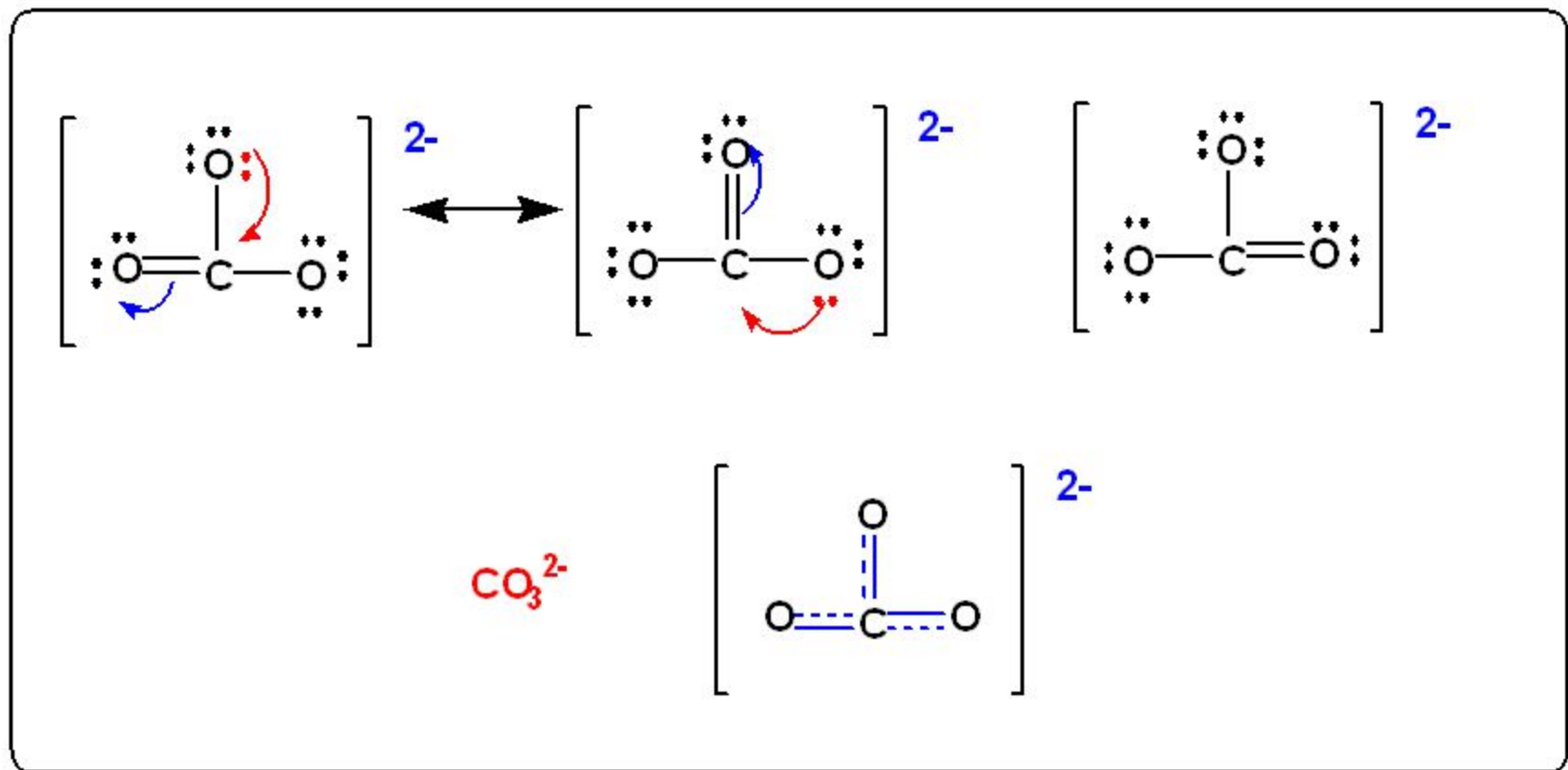


All C-O bonds are 128 pm in length

The C-O bond energy is 528 kJ/mol

The Lewis structure model is too simple to represent a molecule or ion exhibiting resonance.

We need three Lewis structures to approximate the representation of the carbonate ion.



The **carbonate ion** has three equivalent C-O bonds, of a length typical of 1 and 1/3 bond, for a **1.33 bond order**.