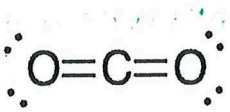
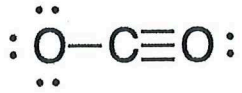
BONDING & STRUCTURE AHL (HL only)

Please ensure that you have also completed the Core (SL & HL) questions

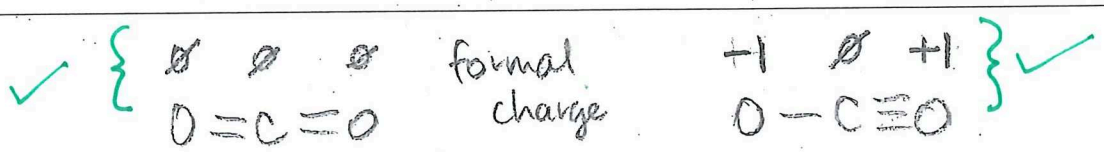
1. When drawing a Lewis (electron dot) structure for carbon dioxide (CO_2) it is possible to draw two Lewis structures that adhere to the 'octet rule':





(a) Assign **formal charges** to each of the atoms in these structures, and state, with a reason, which is the most stable Lewis structure.

[3]



Left hand structure is the most stable as the atoms have no formal charges. ✓

(b) State the hybridisation of the **oxygen** atoms in each of the structures.

[2]

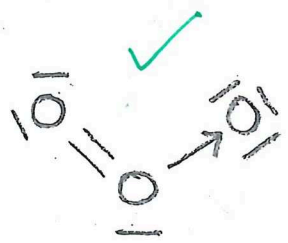
Both sp^2 in left hand structure. ✓

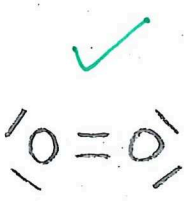
one sp^3 and one sp in the right hand structure. ✓

2. (a) Ozone (O_3) and oxygen (O_2) are both present in the atmosphere.

(i) Draw Lewis (electron dot) structures to represent both O_3 and O_2.

[2]





allow any combination of lines / dots / crosses.

(ii) Explain why both bonds in the ozone molecule are the same length. You may wish to draw a diagram.

[1]

diagram or statement ✓

ozone shows resonance / electrons are delocalised.

(iii) Using section 10 of the data book, predict the bond lengths in the ozone molecule.

[1]

Both 134·5 (pm) ✓

(allow any value between 121 and 148)

(iv) Describe the difference in bond strengths in ozone and oxygen, and how this affects the energy of radiation reaching the Earth's surface.

[2]

Bonds in oxygen are stronger than bonds in ozone. ✓

So oxygen absorbs radiation of a higher energy / frequency (lower wavelength) than ozone ✓ (reducing the amount reaching the Earth's surface).

(v) When oxygen absorbs radiation, homolytic fission may occur. Determine the wavelength of light absorbed by a single molecule of oxygen. Use sections 1, 2 and 11 of the data book. Show your working.

[2]

From data book bond energy O=O is 498 kJ mol^{-1}

Energy per molecule $= \frac{498000\ J}{6.02 \times 10^{23}} = 8.27... \times 10^{-19}\ J$ ✓

$\lambda = hc/E$

$\lambda = \frac{6.63 \times 10^{-34}\ Js \times 3.00 \times 10^{8}\ ms^{-1}}{8.27... \times 10^{-19}\ J} = 2.40 \times 10^{-7}\ m$ ✓ (3 sig figs)

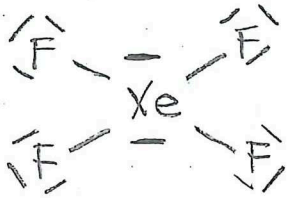
(units not required)

3. (a) VSEPR theory can be used to predict the shapes of molecules, like xenon tetrafluoride (XeF_4), iodine trifluoride (IF_3) and the phosphorus hexachloride ion (PCl_6^-).

(i) Draw Lewis (electron dot) structures to represent XeF_4, IF_3 and PCl_6^-. State the **shapes** of the molecules/molecular ion.

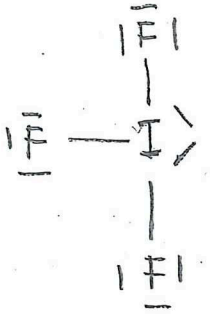
[6]

allow any combination of lines/dots/crosses.

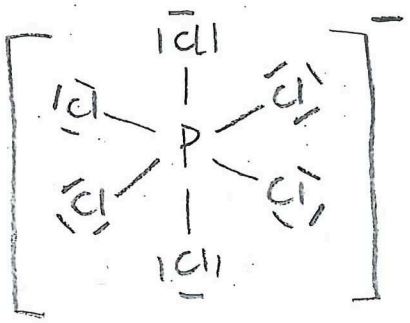


square planar ✓

penalise missing lone-pairs once only.



T-shaped ✓



octahedral ✓

charge is required

(ii) Determine which of XeF_4, IF_3 and PCl_6^- would be *polar*. Outline your reasoning.

[3]

XeF_4 and PCl_6^- not polar as they are symmetrical /dipoles cancel/have zero dipole moment. ✓

IF_3 is polar ✓

As it is not symmetrical and has polar bonds/ I and F have different electronegativities. ✓

4. Ethane (C_2H_6) has only single bonds, ethene (C_2H_4) has one double bond and ethyne (C_2H_2) has one triple bond.

(a) The bonding in these molecules may also be described in terms of *sigma* and *pi* bonds.

(i) Explain what is meant by the terms *sigma bond* and *pi bond*.

[2]

A sigma bond is the overlap of atomic orbitals along the internuclear axis. ✓

A pi bond is the overlap of atomic orbitals above and below the internuclear axis. ✓

(ii) Describe the double bond in ethene and the triple bond in ethyne in terms of sigma and pi bonds.

[2]

the C=C double bond consists of one sigma and one pi bond. ✓

The C≡C triple bond consists of one sigma and two pi bonds. ✓

(b) Explain the term *hybridization,* and state the hybridization of the carbon atoms in ethane, ethene and ethyne.

[4]

Hybridization is the mixing of atomic orbitals to produce hybrid atomic orbitals. ✓

carbon is ethane ✓ is sp^3 hybridized.

carbon is ethene ✓ is sp^2 hybridized

carbon is ethyne ✓ is sp hybridized.

Total Marks 30 (45 minutes)