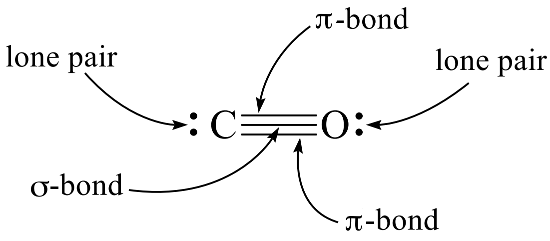
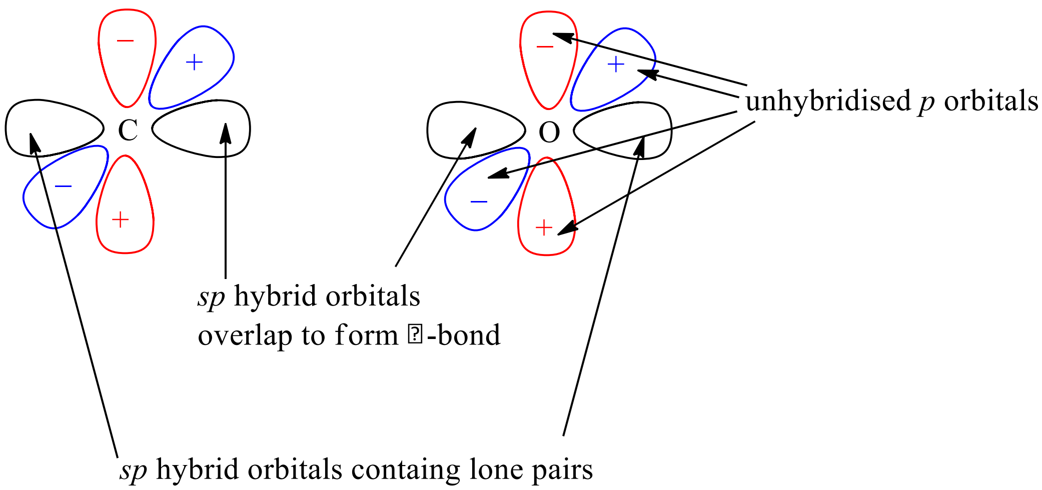
Marks
**5**

- Carbon monoxide is a poisonous gas that may be obtained from incomplete combustion. Draw the Lewis structure of carbon monoxide and add the labels *lone pair, σ-bond, π-bond* as appropriate.




On the atoms below, draw and label the orbitals (atomic and/or hybridised) that give rise to the bonds and lone pairs on carbon monoxide and clearly show which orbitals overlap with each other and the type of bond that results.




**Unhybridised atomic *p* orbitals overlap to form a π-bond. The lobes of the red orbitals are in the plane of the paper whilst those of the blue orbitals are perpendicular to the plane of the paper.**

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

Marks

- In the spaces provided, briefly explain the meaning of the following terms. 1

Ionic bonding

**The electrostatic attraction between cations and anions. It is long range and non-directional and depends on the magnitude of the charges and the sizes of the ions. Typical of bonding between a group 1 or 2 metal with a group 16 or 17 non-metal.**

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

**Marks**
**3**

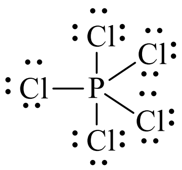
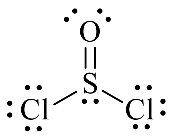
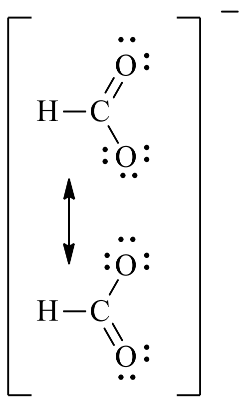
- Silicon and carbon are both in Group 14 and form dioxides. Carbon dioxide is a gas at room temperature while silicon dioxide (sand) is a solid with a high melting point. Describe the bonding in these two materials and explain the differences in properties they show.

**$CO_2$ contains discrete molecules. Carbon makes four bonds by making two C=O double bonds. The C=O double bonds have strong σ and π components. Although these bonds are quite polar, these molecules are linear and do not possess dipole moments. Only very weak dispersion intermolecular forces hold the molecules together and $CO_2$ is a gas at room temperature.**

**$SiO_2$ is a network covalent solid. Each silicon makes four bonds by making four Si-O single bonds. The covalent network leads to a very strongly bonded solid with a very high melting point.**

Marks 3

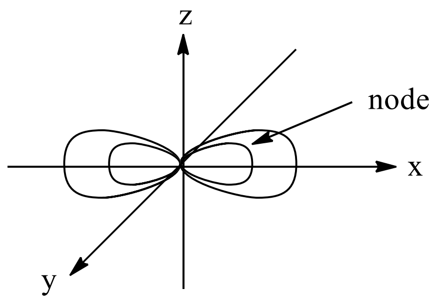
- Complete the following table, include resonance structures if appropriate. The central atom is underlined.

| Formula | <u>P</u>Cl$_5$ | <u>S</u>OCl$_2$ | H<u>C</u>OO$^-$ |
|---|---|---|---|
| Lewis structure |  |  |  |

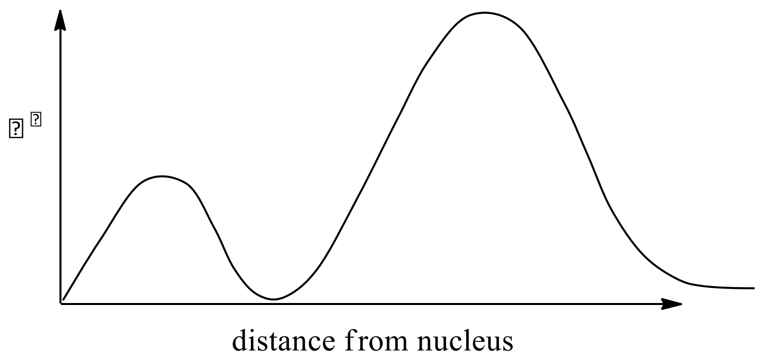
**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

**Marks**
**4**

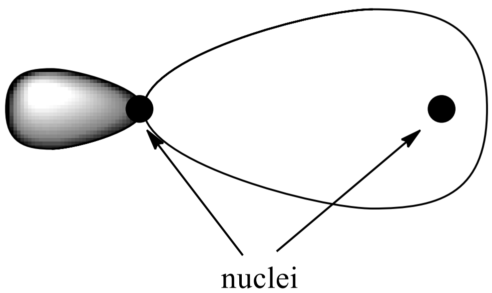
- Sketch the shape of a $3p_x$ orbital.




Sketch the radial probability ($\psi^2$) of an electron in a $3p_x$ orbital.




Sketch the shape of the σ orbital formed by overlap of a $3p_x$ orbital and an *s* orbital. Clearly show the position of the two nuclei.



- The intense yellow light emitted from a sodium street lamp has a wavelength of $\lambda$ = 590 nm. The light is emitted when an electron moves from a 3*p* to a 3*s* orbital. What is the energy of (a) one photon and (b) one mole of photons of this light? **5**

**The energy of a photon with wavelength $\lambda$ is given by $E = hc / \lambda$. Hence:**

$$E = (6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^{8} \text{ m s}^{-1}) / (590 \times 10^{-9} \text{ m}) = 3.4 \times 10^{-19} \text{ J}$$

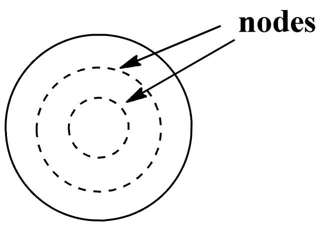
**This is the energy per photon. The energy per mole is therefore:**

$$E = (6.022 \times 10^{23} \text{ mol}^{-1}) \times (3.4 \times 10^{-19} \text{ J}) = 2.0 \times 10^{2} \text{ kJ mol}^{-1}$$

| | |
|---|---|
| (a) Answer: **$3.4 \times 10^{-19}$ J** | (b) Answer: **$2.0 \times 10^{2}$ kJ mol$^{-1}$** |

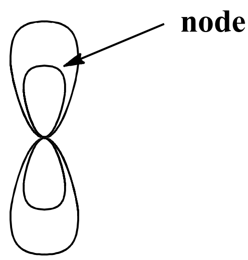
Sketch the shape of a 3*s* and a 3*p* orbital and label any spherical nodes that may be present.

3*s* orbital




**3*s* orbital**

3*p* orbital



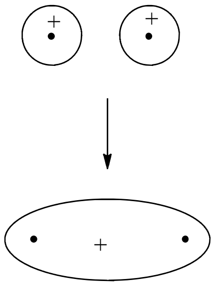

**3*p* orbital**

What does a node represent?

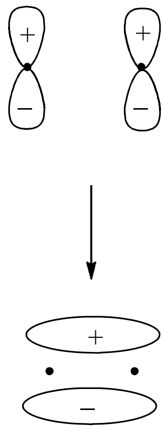
**A node represents the region where there is zero probability of finding the electron.**

**Marks**

- Consider the σ-bond of a hydrogen molecule and the π-bond of ethylene ($H_2C=CH_2$). Sketch the shapes of the molecular orbitals of these bonds and the shapes of the atomic orbitals from which they arise. **2**

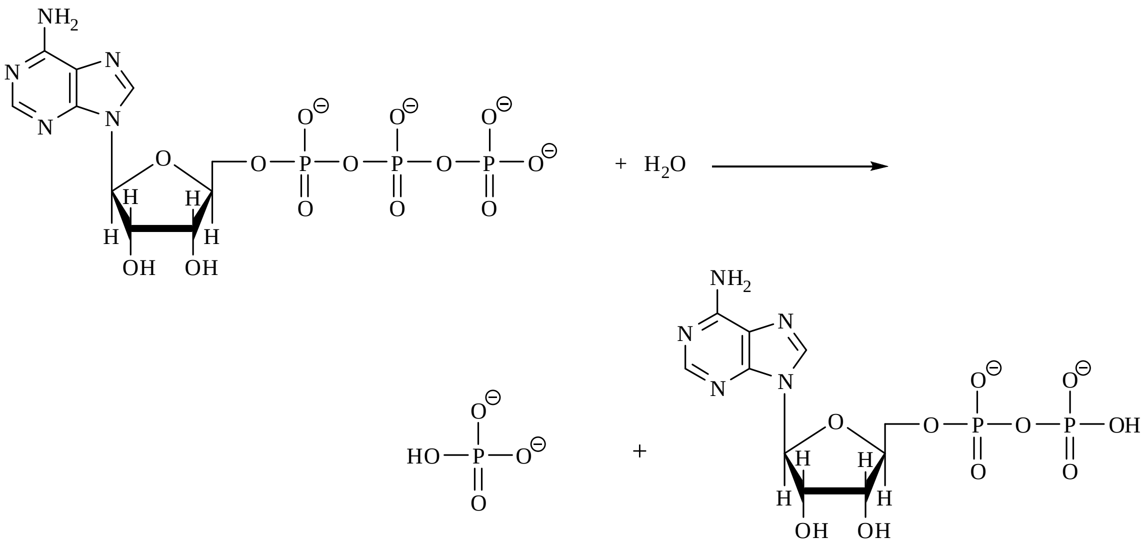



hydrogen




ethylene

- ATP is used as an energy source in the body. Hydrolysis releases ADP, $HPO_4^{2-}$ and energy, according to the equation: **2**




Suggest **two** reasons why this reaction is a good energy source.

**There is an increase in resonance stabilisation energy when a free $HPO_4^{2-}$ ion is produced.**

**ATP is a high energy molecule due to the 4 negative charges near each other. This is reduced when it's converted to ADP which has only 2 close negative charges.**

**Marks**
**2**

- Complete the following table, giving either the systematic name or the molecular formula as required.

| Formula | Systematic name |
|---|---|
| $NaHSO_4$ | **sodium hydrogensulfate** |
| **$AsCl_3$** | arsenic(III) chloride |
| $CrCl_3 \cdot 6H_2O$ | **chromium(III) chloride-6-water** |
| **$Ag_2Cr_2O_7$** | silver dichromate |

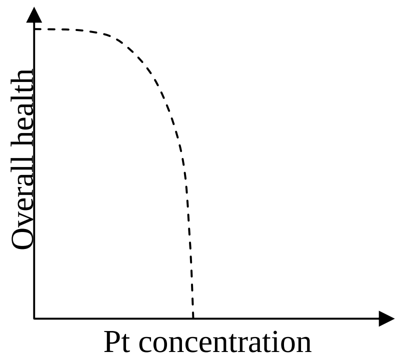
• Like most medicines, the platinum complex, cisplatin, *cis*-[$PtCl_2(NH_3)_2$], is both effective and toxic. What is cisplatin used to treat? **4**

**Cisplatin is used to treat a number of cancers, including testicular and ovarian cancer.**

What does the cisplatin react with in the body to cause most of the toxicity?

**Sulfur containing enzymes in the kidneys**

Draw a graph showing the relationship between overall health and the level of platinum in the body of a healthy person.

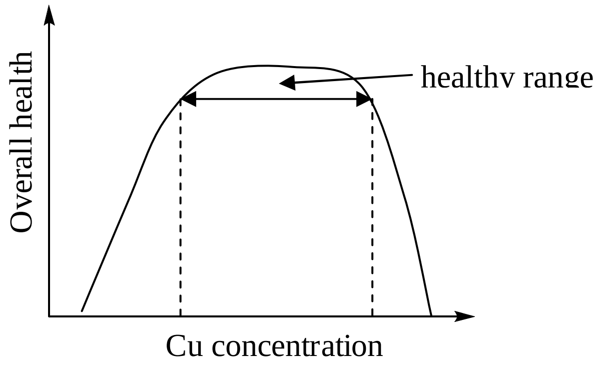


**Marks**
**2**

- Complete the following table, giving either the systematic name or the molecular formula as required.

| Formula | Systematic name |
|---|---|
| $SO_2$ | **sulfur dioxide** |
| $CoCl_2 \cdot 6H_2O$ | **cobalt(II) chloride-6-water** |
| **$Ag_2CrO_4$** | silver chromate |
| **$KHCO_3$** | potassium hydrogencarbonate |

- Copper is an essential element in human biology, deficiencies leading to blood disorders. Excess copper can occur in cases of poisoning or in Wilson's disease. Draw a graph showing the relationship between overall health and the level of copper in the body and identify the 'healthy' range. **4**




Describe one biological function of copper.

**Copper enzymes are involved in electron transport systems due to the ability of copper to change its oxidation state.**

**In some organisms, copper enzymes are involved in oxygen transport.**

Suggest one approach for treating an excess level of copper.

**Treatment with a complexing agent such as EDTA leads to the formation of stable water-soluble complex that can be excreted from the body.**

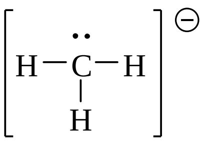
Marks

- Complete the following table. Give, as required, the formula, the systematic name, the oxidation number of the underlined atom and, where indicated, the number of *d* electrons for the element in this oxidation state. **5**

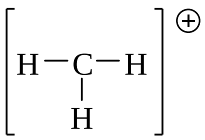
| Formula | Systematic name | Oxidation number | Number of *d* electrons |
|---|---|---|---|
| $\underline{C}O_2$ | **carbon dioxide** | **+IV or +4** | **0** |
| $Na_2\underline{Cr}O_4$ | **sodium chromate** | **+VI or +6** | **0** |
| $\underline{Fe}Cl_3{\cdot}3H_2O$ | **iron(III) chloride-3-water (the non-IUPAC form "iron(III) chloride trihydrate" is also acceptable)** | **+III or +3** | **5** |
| **$K_2SO_4$** | potassium sulfate | | |

- Draw the Lewis structures, showing all valence electrons for the following species. **3**

$CH_3^-$



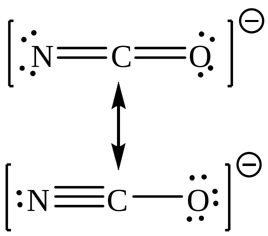
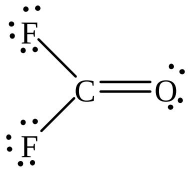
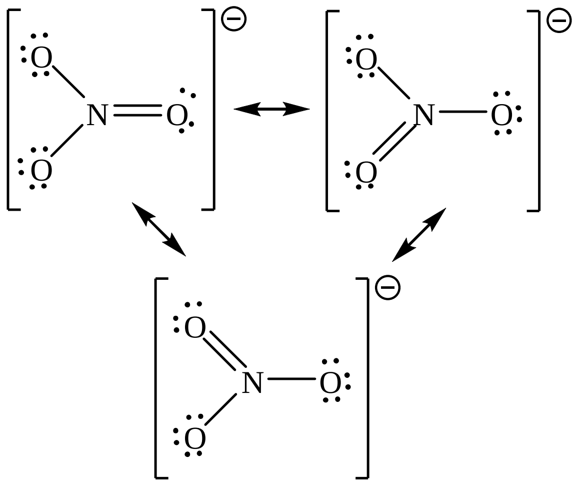
$CH_3^+$



Indicate which of these species you expect will be more stable and explain why.

**$CH_3^-$ is more stable as it has a full octet of electrons**

- Draw the Lewis structures, showing all valence electrons for the following species. Indicate which of the species have contributing resonance structures. **4**

| $NCO^-$ | $COF_2$ | $NO_3^-$ |
|---|---|---|
|  |  |  |
| Resonance: **YES** / NO | Resonance: YES / **NO** | Resonance: **YES** / NO |