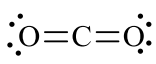
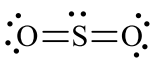
Marks 12

- Complete the following table.

Molecule	CO_2	SO_2
Draw a Lewis structure		
Name the molecular geometry	**linear**	**bent (approx 120°)**
Does the molecule have a dipole moment? Give a reason for your answer.	**No. The molecule is linear so the dipoles in the C=O bonds cancel each other out.**	**Yes. The molecule is bent so the dipoles in the S=O bonds do not cancel each other out.**
Give the hybridisation of the central atom.	***sp***	***sp*^{2}**

Comment on the relative strength of a π-bond in carbon dioxide compared to a π-bond in sulfur dioxide.

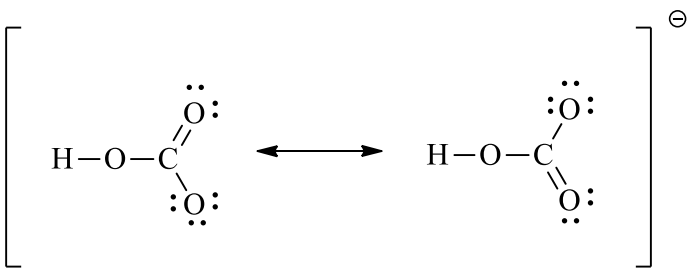
The π-bond is stronger in CO_2 because the overlapping orbitals (2*p* in C and 2*p* in O) are of similar size allowing maximum overlap. In SO_2, the 3*p* orbital in S is bigger than the 2*p* orbital in O so the overlap is not as good.

Both oxides dissolve in water to give a weak acid. Choose one of the oxides and write balanced equations representing the formation of the corresponding weak acid and the dissociation of the acid into ions.

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq) \rightarrow H^+(aq) + HSO_3^-(aq)$

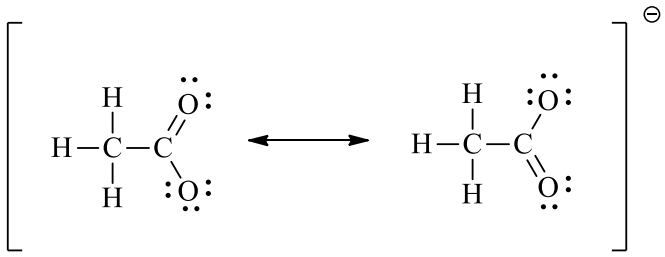
$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq) \rightarrow H^+(aq) + HCO_3^-(aq)$

Use one of the molecules/ions from the above equations to illustrate the concept of resonance.



Marks 10

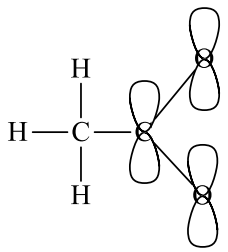
- Draw the Lewis structure of the acetate ion (CH_3COO^-) showing all appropriate resonance structures.



Indicate the hybridisation, molecular geometry and approximate bond angle about each of the carbon atoms in the acetate ion.

	$-CH_3$	$-COO^-$
Hybridisation of C	***sp*^{3}**	***sp*^{2}**
Molecular geometry about C	**tetrahedral**	**trigonal planar**
Approximate bond angles about C	**109^o**	**120^o**

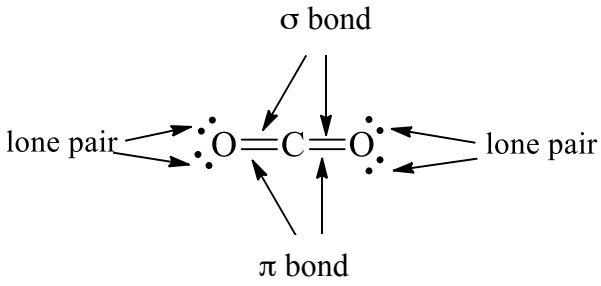
The actual structure of the acetate ion is a weighted combination of all resonance structures. Sketch the σ-bond framework of the acetate ion and indicate the *p*-orbitals that are involved in the π-bonding of the acetate ion.



How many electrons are involved with the π-bonding? **4**

What is the hybridisation of the oxygen atoms in the acetate ion? ***sp*^{2}**

• Draw the Lewis structure of carbon dioxide and label the electron pairs as either 'σ-bond' or 'π-bond' or 'lone pair'.	**Marks 4**



What is the hybridisation of the carbon atom and the oxygen atoms?

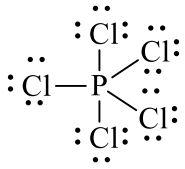
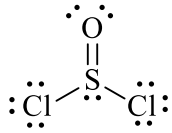
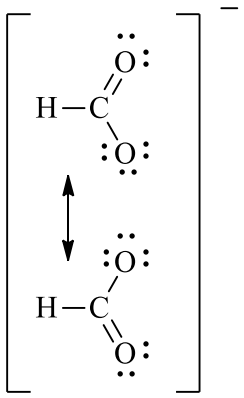
C: ***sp***	O: sp^2

Does carbon dioxide have a permanent dipole moment? Explain your reasoning.

As oxygen is more electronegative than carbon. The shared electrons in this bond lie more towards the oxygen. Each C–O bond is polar.

However, the symmetry of the molecule means that the 2 bond moments cancel each other. Overall, there is no permanent dipole moment.

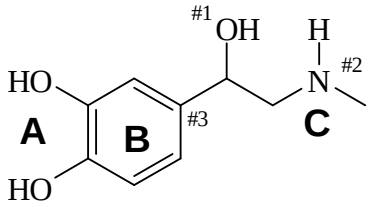
• Complete the following table, include resonance structures if appropriate. The central atom is underlined. **Marks 7**

Formula	$\underline{P}Cl_5$	$\underline{S}OCl_2$	$H\underline{C}OO^-$
Lewis structure			
Arrangement of electron pairs around the underlined atom	**trigonal bipyramidal**	**tetrahedral**	**trigonal planar**
Molecular geometry	**trigonal bipyramidal**	**trigonal pyramidal**	**trigonal planar**
Intermolecular forces present	**dispersion**	**dispersion and dipole-dipole**	

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

Marks 4

- The molecular structure of adrenaline (epinephrine), a hormone involved in the "fight or flight" response, is shown below.

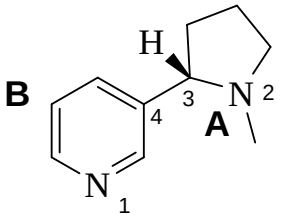


Provide the requested information for each of the indicated sites on adrenaline.

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry around the atom	Approximate angles around the atom
$^{\#1}$O	**tetrahedral**	***sp*^{3}**	**bent**	**109°**
$^{\#2}$N	**tetrahedral**	***sp*^{3}**	**trigonal pyramidal**	**109°**
$^{\#3}$C	**trigonal planar**	***sp*^{2}**	**trigonal planar**	**120°**

Marks 4

- The molecular structure of nicotine, the addictive component of tobacco, is shown below.



List the types of intermolecular interactions that each of the following sites on nicotine would be involved in when it is dissolved in water.

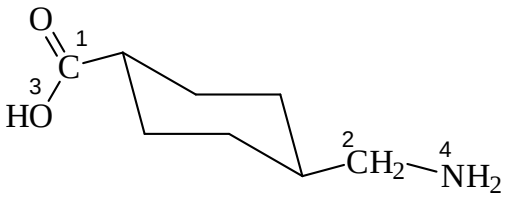
A – H bonding and dipole-dipole interactions
B – dispersion forces and dipole-induced dipole

Provide the requested information for each of the indicated atoms in nicotine.

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry around the atom
N-1	**trigonal planar**	***sp*^{2}**	**bent (~120°)**
N-2	**tetrahedral**	***sp*^{3}**	**trigonal pyramidal**
C-3	**tetrahedral**	***sp*^{3}**	**tetrahedral**
C-4	**trigonal planar**	***sp*^{2}**	**trigonal planar**

Marks 4

- Tranexamic acid, *trans*-(4-aminomethyl)cyclohexanecarboxylic acid, is used for the treatment of severe haemorrhage in patients with haemophilia.



Provide the requested information for each of the indicated atoms in tranexamic acid.

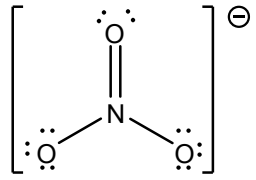
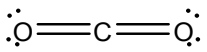
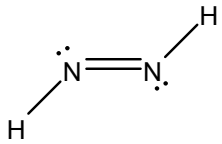
Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry/shape of σ-bonding electron pairs around the atom
C-1	**trigonal planar**	**sp^2**	**trigonal planar**
C-2	**tetrahedral**	**sp^3**	**tetrahedral**
O-3	**tetrahedral**	**sp^3**	**bent**
N-4	**tetrahedral**	**sp^3**	**trigonal pyramidal**

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
$\underline{S}O_3$	**sulphur trioxide**	**+VI**	**0**
$K\underline{Mn}O_4$	**potassium permanganate**	**+VII**	**0**
$\underline{Co}Cl_2 \cdot 6H_2O$	**cobalt(II) chloride hexahydrate**	**+II**	**7**
$(NH_4)_2SO_4$	ammonium sulfate		

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

NO_3^-	CO_2	N_2H_2
		
Resonance: **YES** / NO	Resonance: YES / **NO**	Resonance: YES / **NO**

- A sample of carboxypeptidase (an enzyme) was purified and found on analysis to contain 0.191% by weight of zinc. What is the *minimum* molecular weight of the enzyme if we assume it is a monomer? **2**

The enzyme must contain at least one zinc atom. If it contains one zinc atom, its contribution to the molar mass is 65.39 amu. If this is 0.191% of the total mass, the molar mass corresponding to 100% is:

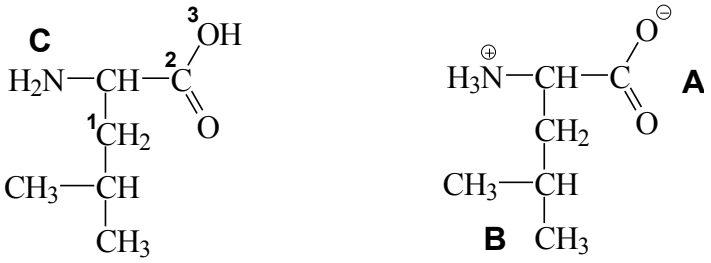
0.191 % of molar mass = 65.39

100% of molar mass = 65.39 / 0.00191 = 34240 g mol^{-1}

Answer: **34240 g mol^{-1} or 34.24 kg mol^{-1}**

Marks 2

- Shown here are the classical and the zwitterionic forms of the amino acid leucine.



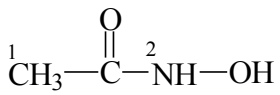
List the types of intermolecular interactions in which each of the indicated sites (**A**, **B** and **C**) in leucine could be involved.

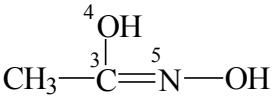
A	**ion-ion, ion-dipole, ion-induced dipole**
B	**dispersion**
C	**hydrogen bonding, dipole-dipole, dipole-induced dipole**

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of the atom	Geometry/shape of σ-bonding electron pairs around the atom
^{1}C	**tetrahedral**	sp^3	**tetrahedral**
^{2}C	**trigonal planar**	sp^2	**trigonal planar**
^{3}O	**tetrahedral**	sp^3	**bent**

Marks 7

- Siderophores (from the Greek meaning 'iron carriers') are organic molecules produced by microorganisms to provide essential Fe^{3+} required for growth. The functional group (the group which binds Fe^{3+}) of siderophores is shown below as tautomers **I** and **II**. Complete the table below, relating to the molecular geometry about the specified atoms in **I** and **II**.

I 

II 

Atom	Geometric arrangement of the electron pairs around the atom	Hybridisation of atom	Geometry of bonding electron pairs around atom
^{1}C	**tetrahedral**	sp^3	**tetrahedral**
^{2}N	**tetrahedral**	sp^3	**trigonal pyramidal**
^{3}C	**trigonal planar**	sp^2	**trigonal planar**
^{4}O	**tetrahedral**	sp^3	**bent**
^{5}N	**trigonal planar**	sp^2	**bent**

Desferal is a siderophore-based drug that is used in humans to treat iron-overload. One molecule of Desferal (molecular formula: $C_{25}H_{48}O_8N_6$) can bind one Fe^{3+} ion. A patient with iron-overload had an excess of 0.637 mM Fe^{3+} in his bloodstream. Assuming the patient has a total blood volume of 5.04 L, what mass of Desferal would be required to complex all of the excess Fe^{3+}?

In 5.04 L, the number of moles of Fe^{3+} is given by the concentration × volume:

$$\textbf{moles of } Fe^{3+} = (0.637 \times 10^{-3} \text{ mol } L^{1}) \times (5.04 \text{ L}) = 3.2105 \times 10^{-3} \text{ mol}$$

As each desferal molecule binds one Fe^{3+}, this is also the number of moles of desferal that is required. The molar mass of desferal is:

$$\textbf{molar mass} = (25\times12.01\text{ (C)} + 48\times1.008\text{ (H)} + 8\times16.00\text{ (O)} + 6\times14.01\text{ (N)}) \text{ g mol}^{-1}$$
$$= 560.964 \text{ g mol}^{-1}$$

The mass of desferal required is then the number of moles × molar mass:

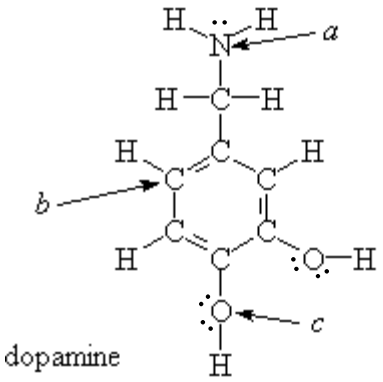
$$\textbf{mass of desferal} = (3.2105 \times 10^{-3} \text{ mol}) \times (560.964 \text{ g mol}^{-1}) = 1.80 \text{ g}$$

ANSWER: **1.80 g**

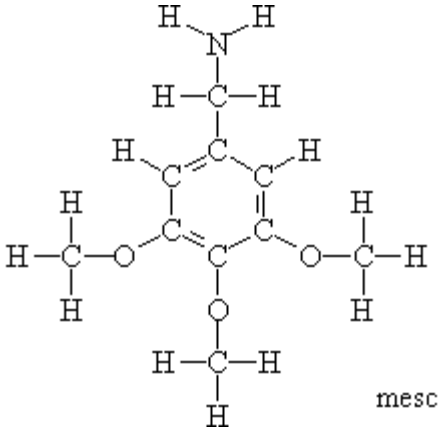
THIS QUESTION CONTINUES ON THE NEXT PAGE

Marks 6

- The structures of dopamine and mescaline are given below.



dopamine


mescaline

Dopamine is involved in the transmission of nerve impulses in the brain. Complete the Lewis structure for dopamine by including all lone pair electrons.

How many π electrons are there in dopamine?

1 lone pair on each O and the π electrons in the 3 C=C bonds are involved in π bonding: 10 e^- in total

Predict the bond angles at the points labelled *a*, *b*, and *c* in dopamine.

a	**~109.5°**
b	**~120°**
c	**~109.5**

Mescaline is an hallucinogenic compound found in the peyote cactus. Suggest a reason for the ability mescaline to disrupt nerve impulses.

Mescaline has a similar structure to dopamine, with a benzene ring and a amine group plus O groups on the ring. It can bind to the receptors designed for dopamine.

Which compound, dopamine or mescaline, has the higher solubility in water? Give reasons for your answer.

The O-H groups in dopamine are able to form H-bonds with water molecules making it quite soluble. In mescaline, these are ethers groups which will form much weaker H-bonds and so mescaline has a lower solubility.