Marks 5

- Complete the following table. Give, as required, the formula, the systematic name and the principal ions present in a solution prepared by adding the substance to water. For the substances that do not form ions in solution, write N/A in this column.

FORMULA	SYSTEMATIC NAME	PRINCIPAL IONS IN WATER SOLUTION
$MgCl_2$	magnesium chloride	**Mg^{2+}(aq), Cl^{-}(aq)**
Na_2CrO_4	sodium chromate	**Na^{+}(aq), CrO_4^{2-}(aq)**
CO	**carbon monoxide**	**N/A**
HIO	**hypoiodous acid**	H^{+}(aq), IO^{-}(aq)
$Fe(NO_3)_3.6H_2O$	iron(III) nitrate-6-wate	**Fe^{3+}(aq), NO_3^{-}(aq)**

- Electron configurations are governed by three rules: the 'Aufbau Principle', the 'Pauli Exclusion Principle' and 'Hund's Rule of Maximum Spin Multiplicity'. The ground state electron configurations of He, N and O have been written INCORRECTLY, as shown below. For each element, name the electron configuration rule that has been broken.

Element	1s	2s	2p	2p	2p	Name of rule that has been broken
He		↑↓				**Aufbau principle**
N	↑↓	↑↓	↑↓	↑		**Hund's Rule**
O	↑↓	↑↓	↑↑	↑		**Pauli Exclusion Principle**

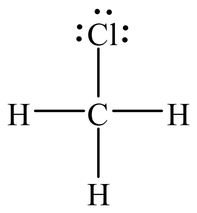
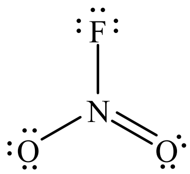
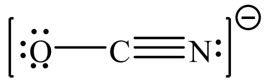
Write the electron configuration of Fe^{2+}

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

What property of iron makes it useful for biological systems?

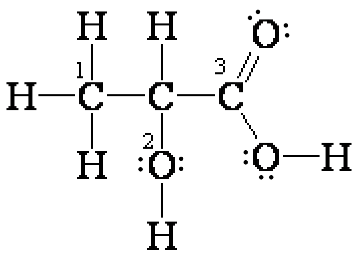
Stability of two oxidation states, Fe^{2+} and Fe^{3+}.

- Draw the Lewis structures, showing all valence electrons for the following species. Indicate which of the molecules possess a dipole. **5**

CH_3Cl	NO_2F	NCO^-
		
Dipole: <u>**YES**</u> / NO	Dipole: <u>**YES**</u> / NO	Dipole: <u>**YES**</u> / NO

Marks
2

- The partial Lewis structure of lactic acid, the molecule that forms in muscle during exercise, is shown below. Complete the Lewis structure of lactic acid by drawing the non-bonded electron pairs around the relevant atoms.



Marks

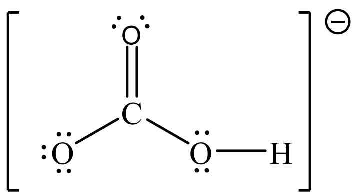
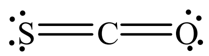
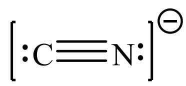
- Complete the following table. Give, as required, the formula, the systematic name, the oxidation number of the underlined atom and, where indicated, the principal ions present in a solution prepared by adding the substance to water. **4**

FORMULA	SYSTEMATIC NAME	OXIDATION NUMBER	PRINCIPAL IONS IN WATER SOLUTION
$\underline{N}O_2$	**nitrogen dioxide**	**+IV**	N/A
$\underline{Pb}(CH_3CO_2)_2$	**lead(II) acetate**	**+II**	**Pb^{2+}(aq), $CH_3CO_2^-$(aq)**
$Mg(ClO_4)_2$	**magnesium perchlorate**		Mg^{2+}(aq); $\underline{Cl}O_4^-$(aq)

Write the full electron configuration of the As^{3+} ion.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

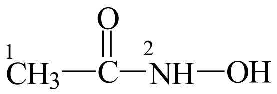
- Draw the Lewis structures, showing all valence electrons for the following species. Indicate which of the species have contributing resonance structures. **5**

HCO_3^-	COS	CN^-
		
Resonance: **<u>YES</u>** / NO	Resonance: YES / **<u>NO</u>**	Resonance: YES / **<u>NO</u>**

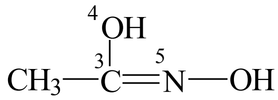
Marks 7

- 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:

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

molar mass = (25×12.01 (C) + 48×1.008 (H) + 8×16.00 (O) + 6×14.01 (N)) g mol^{-1}
= 560.964 g mol^{-1}

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

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

ANSWER: **1.80 g**

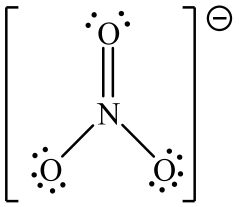
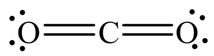
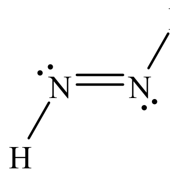
THIS QUESTION CONTINUES ON THE NEXT PAGE

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
$\underline{S}O_3$	**sulfur trioxide**	**+IV**	**0**
$K\underline{Mn}O_4$	**potassium permanganate**	**+VII**	**0**
$\underline{Co}Cl_2{\cdot}6H_2O$	**cobalt(II) chloride-6-water**	**+II**	**7**
NH_4SO_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: **<u>YES</u>** / NO	Resonance: YES / **<u>NO</u>**	Resonance: YES / **<u>NO</u>**

- 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 minimum molecular weight corresponds to the enzyme containing only one zinc atom per molecule, or one mole of the enzyme contains one mole of zinc. The percentage of zinc is given by:

$$\textbf{percentage zinc} = \frac{\textbf{atomic mass of zinc}}{\textbf{molar mass of enzyme}} \times 100 = 0.191$$

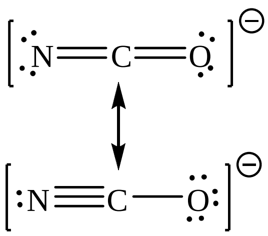
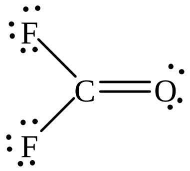
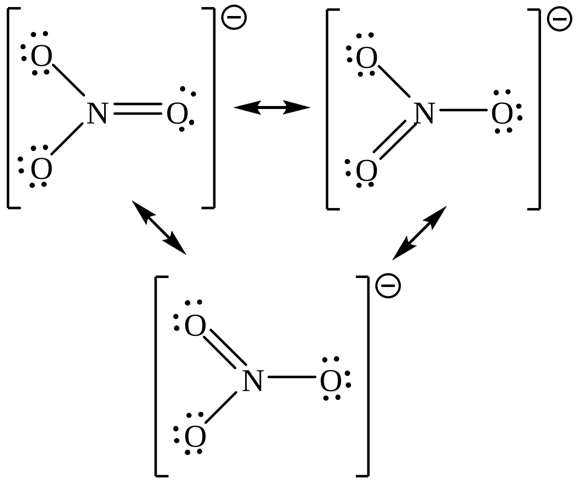
As the atomic mass of zinc is 65.39 g mol^{-1}, this can be rearranged to give the molar mass of the enzyme:

$$\textbf{molar mass of enzyme} = \frac{65.39}{0.00191} = 3.42 \times 10^4 \text{ g mol}^{-1}$$

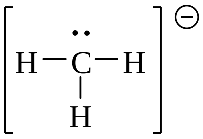
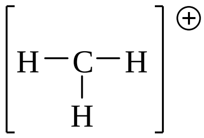
Answer: **3.42×10^4 g mol^{-1}**

4

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

NCO^-	COF_2	NO_3^-
		
Resonance: **<u>YES</u>** / NO	Resonance: YES / **<u>NO</u>**	Resonance: **<u>YES</u>** / NO

- 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

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

Marks
2

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

- The intense yellow light emitted from a sodium street lamp has a wavelength of λ = 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 λ is given by $E = hc / \lambda$. Hence:

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

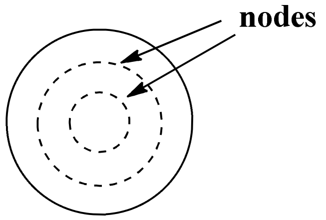
This is the energy per photon. The energy per mole is therefore:

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

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

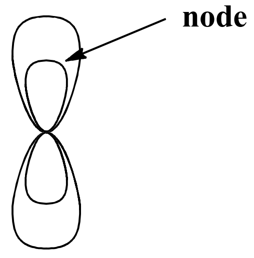
Sketch the shape of a 3*s* and a 3*p* orbital and label any spherical nodes that may be present.

3*s* orbital



3*s* orbital

3*p* orbital



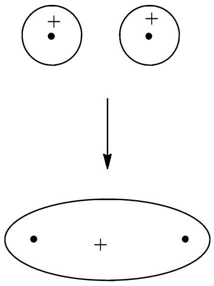
3*p* orbital

What does a node represent?

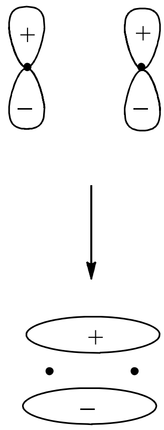
A node represents the region where there is zero probability of finding the electron.

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**

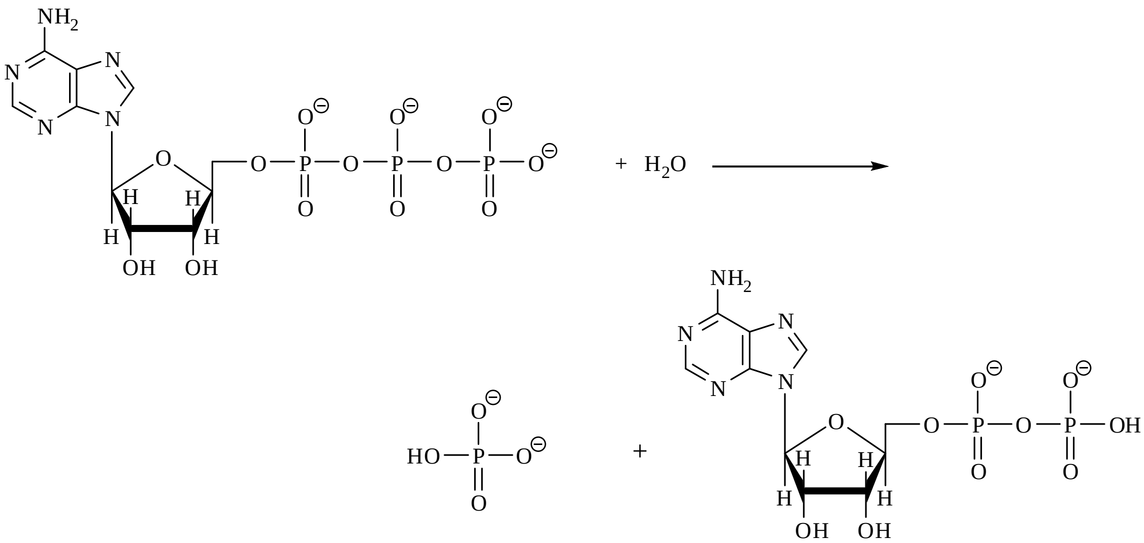


hydrogen



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.