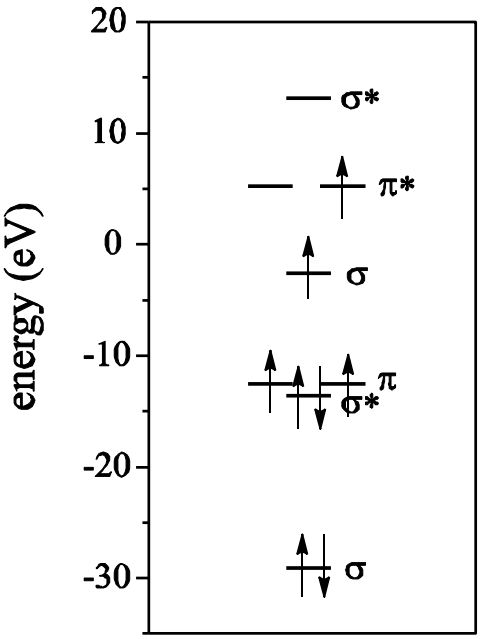
Marks 5

- C_2 is a reaction intermediate observed in flames, comets, circumstellar shells and the interstellar medium. In 2011, a new state of C_2 was observed with 4 parallel spins.

How many *valence* electrons are there in C_2? **8**

Complete the calculated MO diagram for the lowest energy state of C_2 *with 4 parallel spins* by inserting the appropriate number of electrons into the appropriate orbitals.



What is the bond order of this state of C_2? **1**

Is this state paramagnetic? Give reasoning.

Yes. It has 4 unpaired electrons.

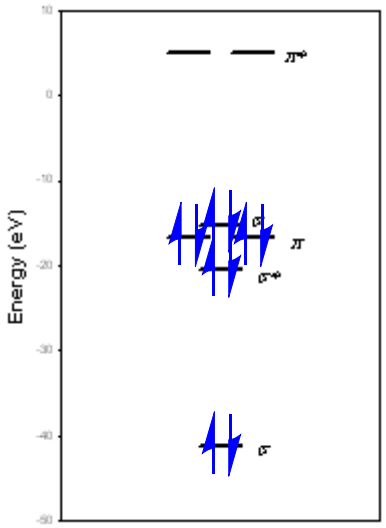
What is the bond order of the ground state of C_2? **2**

	Marks
• Describe two physical properties of liquid or solid water that distinguishes it from 'normal' liquids or solids.	3
The solid is less dense than the liquid. **The density of the liquid can decrease on cooling.** **The melting and boiling points are significantly higher than would be predicted from extrapolation of the other group 16 dihydrides.** **It is capable of dissolving ionic solids to a larger extent than most other liquids.**	
• Molecules with multiple resonance structures are said to be "resonance stabilised". Briefly explain the origin of this extra stability in terms of electron waves and molecular orbitals.	2
The presence of resonance Lewis structures indicates the presence of molecular orbitals that extend over more than a pair of atoms. This greater delocalisation of electrons produces lower energies and hence increased stabilisation of the molecule.	

Marks

- Nitrogen gas constitutes about 78% of the Earth's atmosphere.

  Complete the MO diagram for the valence electrons for the ground state electronic configuration of the nitrogen molecule by inserting the appropriate number of electrons into the appropriate orbitals.



4

Is N_2 paramagnetic or diamagnetic? Explain your answer.

The electrons in N_2 are all paired up – there are as many up as down-spin electrons so that there is no resultant spin. The molecule is diamagnetic.

The N_2^- anion can be generated as a transient species in an electrical discharge. What is the bond order of this molecular ion?

N_2^- has an additional electron in the π^* level. Overall there are 8 bonding electrons (a pair in each σ and two pairs in the π levels) and 3 antibonding electrons (a pair in σ^* and a single electron in π^*). Hence the bond order is:

$\frac{1}{2}(8 - 3) = 5/2$

- Why is the H_2 molecule lower in energy than two isolated H atoms?

2

The electrons are delocalised over two nuclei in H_2, as opposed to being localised around one nucleus in the case of two isolated H atoms. This delocalisation results in an increase in their wavelength and hence a decrease in their momentum from the de Broglie relationship:

$$p = \frac{h}{\lambda}$$

The lower momentum is associated with a lower kinetic energy.