Orbitals & electron spin

Question Paper 1

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Orbitals & electron spin-Atomic structure
Booklet	Question Paper 1

Time Allowed: **36 minutes**

Score: **/30**

Percentage: **/100**

Grade Boundaries:

1 **(a)** Nitrogen and phosphorus are both found in Group 15.

Phosphorus forms more than one allotrope.

(i) Draw a dot-cross diagram to show the bonding in nitrogen, N_2. Show outer electrons only.

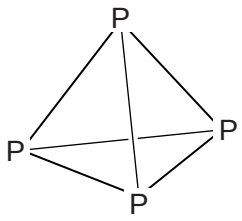
[1]

(ii) What is meant by the term *allotrope*?

.....

..... [1]

(iii) White phosphorus is a solid and exists as P_4 molecules with a tetrahedral structure as shown.



Using the data in Table 1.1 work out the enthalpy change for the following conversion. Include a sign in your answer.

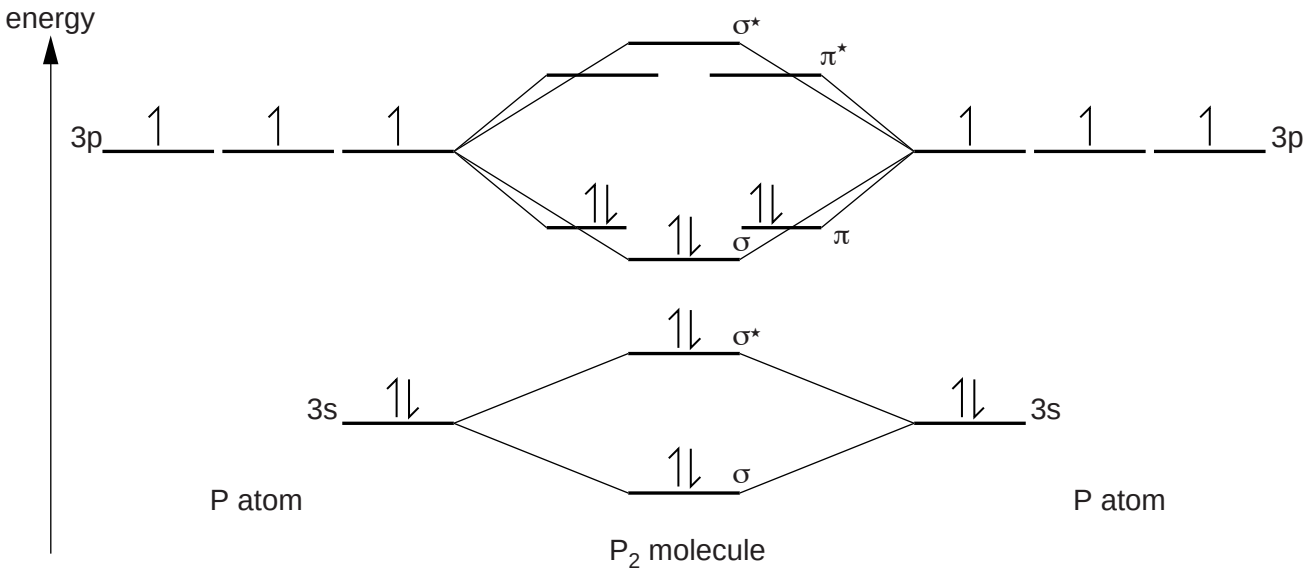
$$P_4(s) \longrightarrow 2P_2(g)$$

Table 1.1

	energy change / kJ mol^{-1}
P−P bond energy	198
P≡P bond energy	485
enthalpy of vaporisation of P_4	12

$\Delta_r H^{\ominus}$ = ... kJ mol^{-1} [3]
sign

(iv) Chemists have recently managed to prepare P_2 molecules in the solid state, trapped in an organic framework (reported in *Nature Chemistry*, 2010). The labelled molecular orbital diagram represents the bonding in P_2, which has a bond order of 3.



Using similar techniques P_2^{2+} and P_2^{+} were also trapped and characterised.

Using the molecular orbital diagram or otherwise, give the bond order in these species.

Bond order in P_2^{2+} = ... Bond order in P_2^{+} = ... [2]

(b) Carbon and silicon are both members of Group 14.

(i) What is meant by the term *first ionisation energy*?

.....

.....

..... [3]

(ii) Explain why the first ionisation energy of silicon is lower than that of carbon.

.....

.....

.....

..... [3]

(iii) State the type of covalent bond typically seen in

- single bonds, ...
- additional bonds in a multiple bond. ..... [1]

(iv) Carbon readily forms multiple bonds with itself, while silicon does not form these bonds so easily.

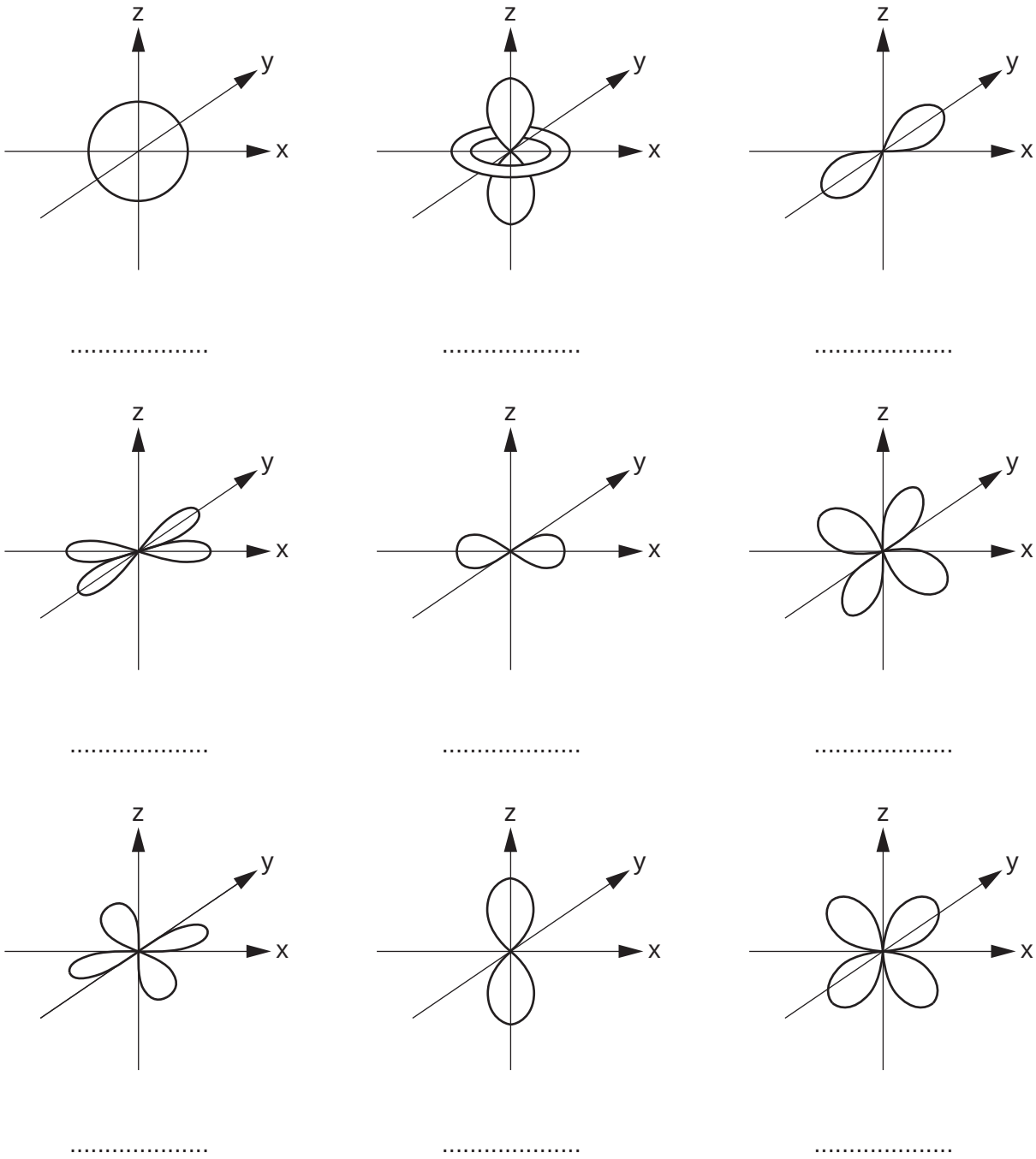
The first compound containing a Si=Si double bond was synthesised in 1972. One such compound contains the following percentages by mass.

C 41.3% H 10.3%

Find the empirical formula of this compound and draw a possible structure, given that it contains only one Si=Si double bond.

structure empirical formula ..... [3]

2. **(a)** **(i)** Sketches of the shapes of the atomic orbitals from the s, p and d subshells are shown below, in random order. Label **each** orbital using labels such as p_x, d_{xy}, etc.



....

....

....

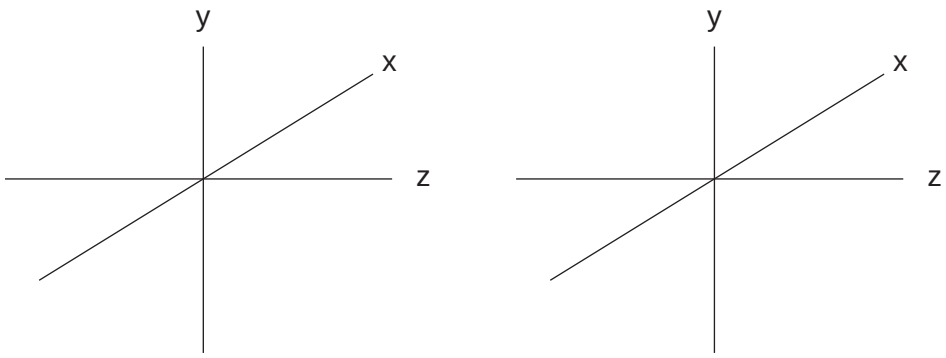
[5]

(ii) There are two elements in the first row of the d block whose gaseous atoms have all their 3d orbitals fully occupied. Name the two elements.

..... and ..... [2]

(b) When the atomic orbitals from two atoms overlap a chemical bond may result. The p orbitals can overlap to form sigma (σ) or pi (π) bonds. When two atoms overlap the *z*-axis is used to define the internuclear axis.

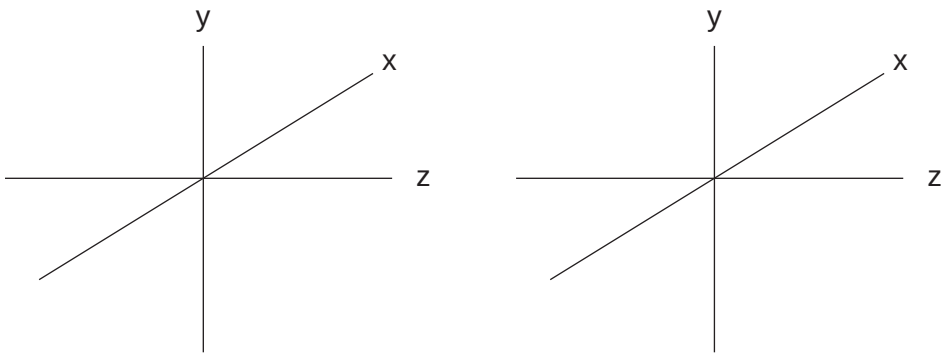
(i) On the diagram below draw two p orbitals (one orbital on each atom) that could overlap to produce a sigma (σ) bond.



atom 1 atom 2

[1]

(ii) On the diagram below draw two p orbitals (one orbital on each atom) that could overlap to produce a **single** pi (π) bond.



atom 1 atom 2

[1]

(c) Transition metal atoms such as chromium sometimes form bonds between themselves using their d orbitals. A compound containing a chromium-chromium quintuple bond (i.e. with a bond order of 5) was recently reported (*Nature Chemistry*, 2009).

(i) Complete the electron configuration of a chromium atom in the gas phase.

[Ar] ..... [1]

(ii) The *z*-axis is used to define the internuclear axis of a chemical bond. Suggest which atomic d orbital can overlap with the same orbital on another atom to form a single sigma (σ) bond.

..... [1]

(iii) The d orbitals of one chromium atom can overlap with d orbitals of the same type on another chromium atom to form pi (π) bonds and delta (δ) bonds. While a single sigma (σ) bond involves the overlap of two orbital lobes in total, and a single pi (π) bond four lobes, a single delta (δ) bond involves the overlap of eight lobes in total. When two atoms overlap the *z*-axis is used to define the internuclear axis.

Suggest two different d orbitals that could be involved in pi (π) bonds, and two different d orbitals that could be involved in delta (δ) bonds.

pi (π): ..... and .....

delta (δ): ..... and ..... [2]

[Total: 13]