

**Section A**

Q1 Three substances, R, S, T, have physical properties as shown.

| substance | mp/°C | bp/°C | electrical conductivity |           |
|-----------|-------|-------|-------------------------|-----------|
|           |       |       | of solid                | of liquid |
| R         | 801   | 1413  | poor                    | good      |
| S         | 2852  | 3600  | poor                    | good      |
| T         | 3550  | 4827  | good                    | not known |

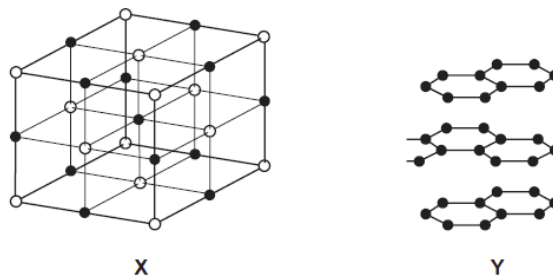
What could be the identities of R, S and T ?

|   | R    | S   | T                |
|---|------|-----|------------------|
| A | NaF  | KCl | Cu               |
| B | NaBr | BaO | SiO <sub>2</sub> |
| C | NaCl | MgO | C [graphite]     |
| D | NaBr | CaO | C [diamond]      |

Q2 In which process are hydrogen bonds broken?

- A  $\text{H}_2(\text{l}) \rightarrow \text{H}_2(\text{g})$   
 B  $\text{NH}_3(\text{l}) \rightarrow \text{NH}_3(\text{g})$   
 C  $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$   
 D  $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{H}(\text{g})$

Q3 The diagram shows part of the lattice structures of solids X and Y.



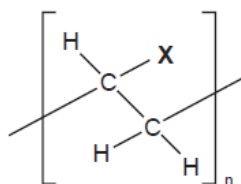
What are the types of bonding present in X and Y?

|   | X        | Y        |
|---|----------|----------|
| A | covalent | metallic |
| B | ionic    | covalent |
| C | ionic    | metallic |
| D | metallic | ionic    |

Q4 The  $\text{CN}^-$  ion is widely used in the synthesis of organic compounds. What is the pattern of electron pairs in this ion?

|   | bonding pairs of electrons | lone pairs on carbon atom | lone pairs on nitrogen atom |
|---|----------------------------|---------------------------|-----------------------------|
| A | 2                          | 1                         | 1                           |
| B | 2                          | 2                         | 1                           |
| C | 3                          | 1                         | 1                           |
| D | 3                          | 1                         | 2                           |

Q5 Plastic bottles for 'fizzy drinks' are made from a polymer with the following structure.



The ability of the polymer to prevent escape of carbon dioxide through the wall of the bottle depends on the ability of the group X to form hydrogen bonds with the carbon dioxide in the drink. Which group X best prevents loss of carbon dioxide?

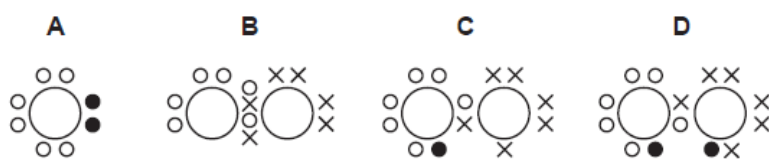
A Cl

B CN

C CO<sub>2</sub>CH<sub>3</sub>

D OH

Q6 When barium metal burns in oxygen, the ionic compound barium peroxide, BaO<sub>2</sub>, is formed. Which dot-and-cross diagram represents the electronic structure of the peroxide anion in BaO<sub>2</sub>?



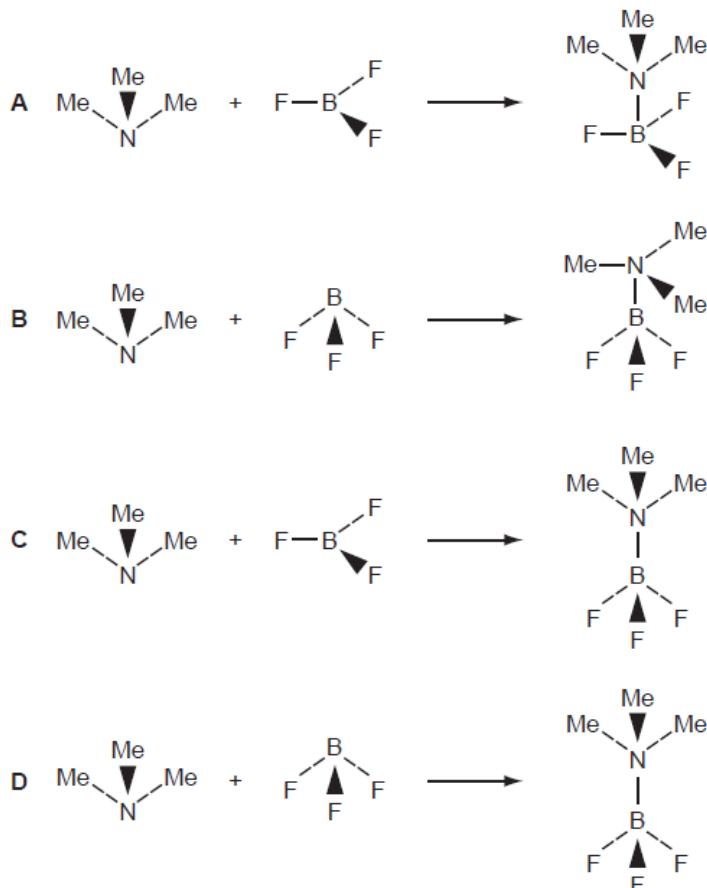
key

○ electron from first oxygen atom

× electron from second oxygen atom

● electron from barium atom

Q7 In this question, the methyl group, CH<sub>3</sub>, is represented by Me. Trimethylamine, Me<sub>3</sub>N, reacts with boron trifluoride, BF<sub>3</sub>, to form a compound of formula Me<sub>3</sub>N.BF<sub>3</sub>. How may this reaction be written in terms of the shapes of the reactants and products?



Q8 Which pair of elements have bonds of the same type between their atoms in the solid state?

- A aluminium and phosphorus  
 B chlorine and argon  
 C magnesium and silicon  
 D sulphur and chlorine

Q9 A crystal of iodine produces a purple vapour when gently heated.

Which pair of statements correctly describes this process?

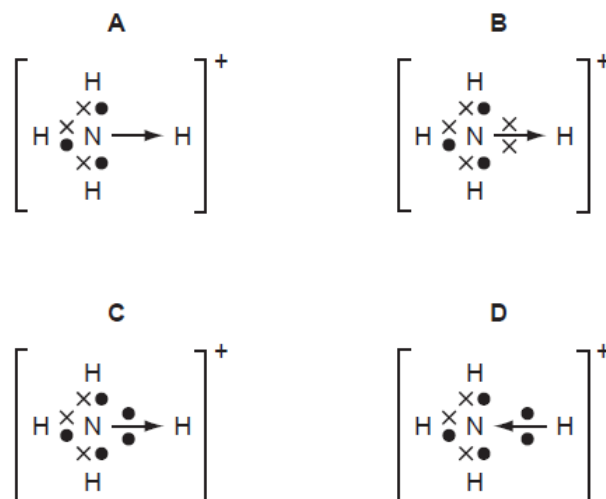
|          | type of bond broken     | formula of purple species |
|----------|-------------------------|---------------------------|
| <b>A</b> | covalent                | I                         |
| <b>B</b> | covalent                | I <sub>2</sub>            |
| <b>C</b> | induced dipole-dipole   | I <sub>2</sub>            |
| <b>D</b> | permanent dipole-dipole | I <sub>2</sub>            |

Q10 Which diagram correctly shows the bonding in the ammonium ion, NH<sub>4</sub><sup>+</sup>?

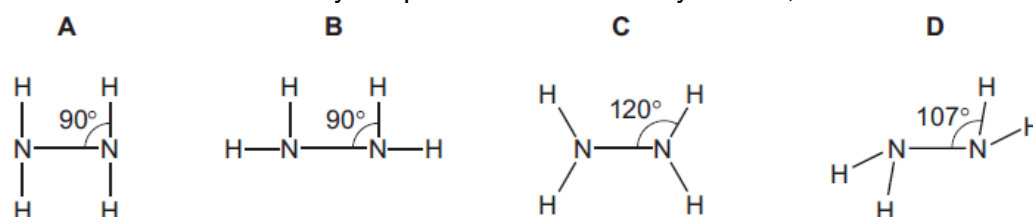
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● N electron

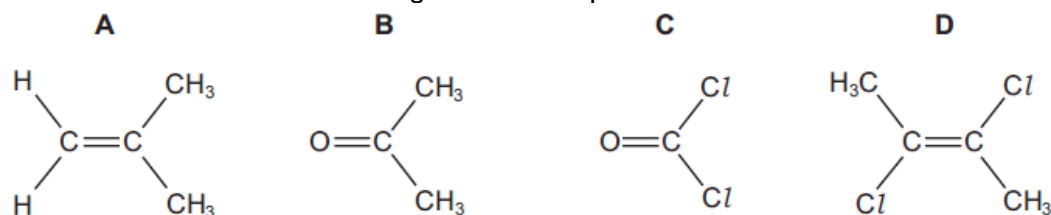
× H electron



Q11 What is the most likely shape of a molecule of hydrazine, N<sub>2</sub>H<sub>4</sub>?



Q12 Which molecule has the largest overall dipole?



Q13 Which compound has a boiling point that is influenced by hydrogen bonding?

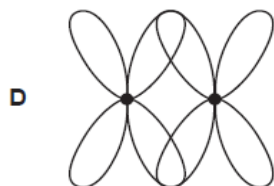
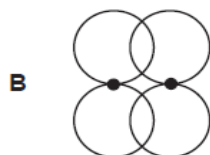
A CH<sub>3</sub>CHO

B CH<sub>3</sub>OCH<sub>3</sub>

C HCO<sub>2</sub>H

D HCO<sub>2</sub>CH<sub>3</sub>

Q14 Which diagram describes the formation of a  $\pi$  bond from the overlap of its orbitals?



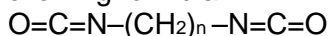
Q15 Magnesium oxide may be used for the lining of an electric furnace for making crockery. Which properties of magnesium oxide help to explain this use?

|   | strong forces between particles | ionic bonding | electrical conductor |
|---|---------------------------------|---------------|----------------------|
| A | yes                             | yes           | no                   |
| B | yes                             | no            | yes                  |
| C | no                              | yes           | no                   |
| D | no                              | no            | yes                  |

Q16 Hydrogen bonding can occur between molecules of methanal, HCHO, and molecules of liquid Y. What could liquid Y be?

- A  $\text{CH}_3\text{OH}$       B  $\text{CH}_3\text{CHO}$       C  $\text{CH}_3\text{COCH}_3$       D  $\text{CH}_3\text{CO}_2\text{CH}_3$

Q17 Lycra is a polyurethane fibre used in the fashion industry. It is a polymer made from two monomers, one of which has the following formula.



What is the O–C–N bond angle in this molecule?

- A  $90^\circ$       B  $109^\circ$       C  $120^\circ$       D  $180^\circ$

Q18 What are the lattice structures of solid diamond, iodine and silicon(IV) oxide?

|   | giant molecular            | simple molecular           |
|---|----------------------------|----------------------------|
| A | diamond, silicon(IV) oxide | iodine                     |
| B | diamond, iodine            | silicon(IV) oxide          |
| C | iodine                     | diamond, silicon(IV) oxide |
| D | silicon(IV) oxide          | diamond, iodine            |

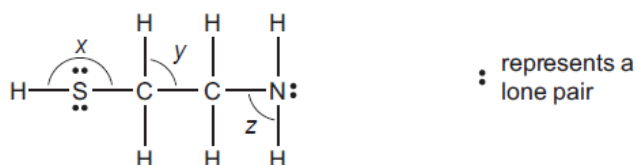
Q19 A substance commonly found in the house or garden has the following properties.

- It is combustible.
- It is an electrical insulator.
- It melts over a range of temperature.

What could the substance be?

- A brass      B paper      C poly(ethene)      D silicon(IV) oxide

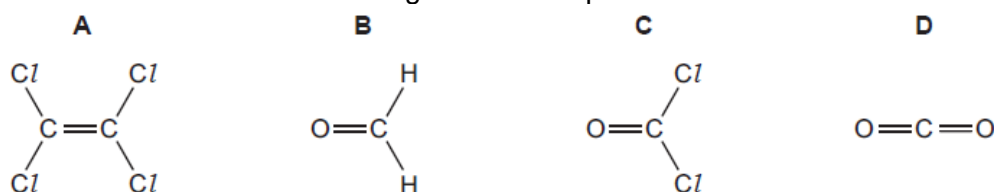
Q20 The antidote molecule shown can help to prevent liver damage if someone takes too many paracetamol tablets.



What is the order of decreasing size of the bond angles x, y and z?

|          | largest | → | smallest |
|----------|---------|---|----------|
| <b>A</b> | x       |   | y        |
| <b>B</b> | x       |   | z        |
| <b>C</b> | y       |   | z        |
| <b>D</b> | z       |   | y        |

Q21 Which molecule has the largest overall dipole?



Q22 The ability of an atom in a covalent bond to attract electrons to itself is called its electronegativity. The greater the difference between the electronegativities of the two atoms in the bond, the more polar is the bond.

Which pair will form the most polar covalent bond between the atoms?

- A chlorine and bromine
- B chlorine and iodine
- C fluorine and chlorine
- D fluorine and iodine

Q23 Which solid has a simple molecular lattice?

- A calcium fluoride
- B nickel
- C silicon(IV) oxide
- D sulfur

Q24 Which molecule or structure does not contain three atoms bonded at an angle between  $109^\circ$  and  $110^\circ$ ?

- A ethanoic acid
- B graphite
- C propane
- D silicon(IV) oxide

Q25 The presence of dipoles helps to explain why the element  $\text{Br}_2$  and the compound  $\text{CHCl}_3$  exist as liquids at room temperature. Which types of dipole are involved?

|          | $\text{Br}_2$                         | $\text{CHCl}_3$                       |
|----------|---------------------------------------|---------------------------------------|
| <b>A</b> | induced dipoles and permanent dipoles | induced dipoles and permanent dipoles |
| <b>B</b> | induced dipoles and permanent dipoles | induced dipoles only                  |
| <b>C</b> | induced dipoles only                  | induced dipoles and permanent dipoles |
| <b>D</b> | induced dipoles only                  | induced dipoles only                  |

Q26 Three compounds have the physical properties shown in the table.

| compound               | P         | Q    | R         |
|------------------------|-----------|------|-----------|
| melting point/°C       | 2852      | 993  | -119      |
| boiling point/°C       | 3600      | 1695 | 39        |
| conductivity (solid)   | poor      | poor | poor      |
| conductivity (liquid)  | good      | good | poor      |
| conductivity (aqueous) | insoluble | good | insoluble |

What might be the identities of P, Q and R?

|   | P                | Q   | R                                |
|---|------------------|-----|----------------------------------|
| A | MgO              | KCl | NH <sub>3</sub>                  |
| B | MgO              | NaF | C <sub>2</sub> H <sub>5</sub> Br |
| C | SiO <sub>2</sub> | KCl | C <sub>2</sub> H <sub>5</sub> Br |
| D | SiO <sub>2</sub> | NaF | HCl                              |

Q27 Sodium borohydride, NaBH<sub>4</sub>, and boron trifluoride, BF<sub>3</sub>, are compounds of boron. What are the shapes around boron in the borohydride ion and in boron trifluoride?

|   | borohydride ion | boron trifluoride |
|---|-----------------|-------------------|
| A | square planar   | pyramidal         |
| B | square planar   | trigonal planar   |
| C | tetrahedral     | pyramidal         |
| D | tetrahedral     | trigonal planar   |

Q28 Some car paints contain small flakes of silica, SiO<sub>2</sub>.

In the structure of solid SiO<sub>2</sub>

- each silicon atom is bonded to x oxygen atoms,
- each oxygen atom is bonded to y silicon atoms,
- each bond is a z type bond.

What is the correct combination of x, y and z in this statement?

|   | x | y | z        |
|---|---|---|----------|
| A | 2 | 1 | covalent |
| B | 2 | 1 | ionic    |
| C | 4 | 2 | covalent |
| D | 4 | 2 | ionic    |

Q29 In which pair do the molecules have the same shape as each other?

- A H<sub>2</sub>O and CO<sub>2</sub>      B H<sub>2</sub>O and SCl<sub>2</sub>      C NH<sub>3</sub> and BH<sub>3</sub>      D SCl<sub>2</sub> and BeCl<sub>2</sub>



Q37 Which physical properties are due to hydrogen bonding between water molecules?

- 1 Water has a higher boiling point than  $\text{H}_2\text{S}$ .
- 2 Ice floats on water.
- 3 The H-O-H bond angle in water is approximately  $104^\circ$ .

Q38 Which statements about covalent bonds are correct?

- 1 A triple bond consists of one  $\pi$  bond and two  $\sigma$  bonds.
- 2 The electron density in a  $\sigma$  bond is highest along the axis between the two bonded atoms.
- 3 A  $\pi$  bond restricts rotation about the  $\sigma$  bond axis.

Q39 Which statements about bond angles are correct?

- 1 The bond angle in  $\text{SO}_2$  is smaller than the bond angle in  $\text{CO}_2$ .
- 2 The bond angle in  $\text{H}_2\text{O}$  is smaller than the bond angle in  $\text{CH}_4$ .
- 3 The bond angle in  $\text{NH}_3$  is smaller than the bond angle in  $\text{BF}_3$ .

Q40 Which of these substances have a giant structure?

- 1 silicon(IV) oxide
- 2 baked clay found in crockery
- 3 phosphorus(V) oxide



1. C
2. B
3. B
4. C
5. D
6. D
7. C
8. D
9. C
10. C
11. D
12. B
13. C
14. B
15. A
16. A
17. D
18. A
19. C
20. C
21. B
22. D
23. D
24. B
25. C
26. B
27. D
28. C
29. B
30. B
31. C
32. B
33. C
34. D
35. A
36. B
37. B
38. C
39. A
40. B

Q1 Ethyne  $C_2H_2$  is a linear molecule with a triple bond between the two carbon atoms. Draw a 'dot-and-cross' diagram of an ethyne molecule.

(June 2006)

Q2 Ethene,  $C_2H_4$ , and hydrazine,  $N_2H_4$ , are hydrides of elements which are adjacent in Periodic Table. Data about ethene and hydrazine are given in the table below.

|                            | $C_2H_4$  | $N_2H_4$ |
|----------------------------|-----------|----------|
| melting point/ $^{\circ}C$ | -169      | +2       |
| boiling point/ $^{\circ}C$ | -104      | +114     |
| solubility in water        | insoluble | high     |
| solubility in ethanol      | high      | high     |

(a) Ethene and hydrazine have a similar arrangement of atoms but differently shaped molecules.

(i) What is the H-C-H bond angle in ethene?

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 (ii) Draw a 'dot-and-cross' diagram for hydrazine.

(iii) What is the H-N-H bond angle in hydrazine?

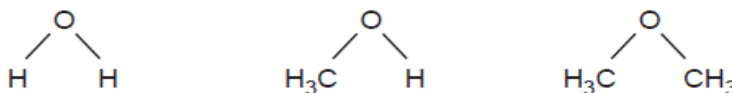
(b) The melting and boiling points of hydrazine are much higher than those of ethene. Suggest reasons for these differences in terms of the intermolecular forces **each** compound possesses.

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 .....  
 .....

(c) Explain, with the aid of a diagram showing lone pairs of electrons and dipoles, why hydrazine is very soluble in ethanol.

(June 2007)

Q3 The structural formulae of water, methanol and methoxymethane,  $\text{CH}_3\text{OCH}_3$ , are given below.



(a)(i) How many lone pairs of electrons are there around the oxygen atom in methoxymethane?

.....  
(ii) Suggest the size of the C–O–C bond angle in methoxymethane.

.....  
Attractive forces between the molecules of compound differ in their strength and include the following.

**A** interactions involving permanent dipoles

**B** interactions involving temporary or induced dipoles

**C** hydrogen bonds

(b) By using the letters **A**, **B**, or **C**, state the **strongest** intermolecular force present in **each** of the following compounds.

Ethanol                       $\text{CH}_3\text{CHO}$                       .....

Ethanol                       $\text{CH}_3\text{CH}_2\text{OH}$                       .....

Methoxymethane               $\text{CH}_3\text{OCH}_3$                       .....

2-Methylpropane               $(\text{CH}_3)_2\text{CHCH}_3$                       .....

(c) Methanol and water are completely soluble in each other.

(i) Which intermolecular force exists between methanol molecules and water molecules that makes these two liquids soluble in each other?

.....  
(ii) Draw a diagram that clearly shows this intermolecular force. Your diagram should show any lone pairs or dipoles present on either molecule that you consider to be important.

(June 2008)

Q4 At low temperatures, aluminium chloride vapour has the formula  $Al_2Cl_6$ . Draw a 'dot-and-cross' diagram to show the bonding in  $Al_2Cl_6$ . Show outer electrons only.

(June 2009)

Q5 Elements and compounds which have small molecules usually exist as gases or liquids.

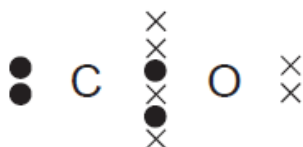
(a) Chlorine,  $Cl_2$ , is a gas at room temperature whereas bromine,  $Br_2$ , is a liquid under the same conditions. Explain these observations.

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 .....

(b) The gases nitrogen,  $N_2$ , and carbon monoxide,  $CO$ , are isoelectronic, that is they have the same number of electrons in their molecules. Suggest why  $N_2$  has a lower boiling point than  $CO$ .

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(c) A 'dot-and-cross' diagram of a  $CO$  molecule is shown below. Only electrons from outer shells are represented.



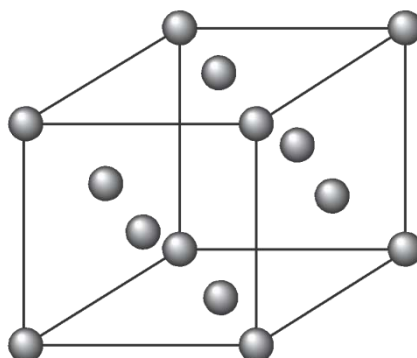
In the table below, there are three copies of this structure.

On the structures, draw a circle round a pair of electrons that is associated with **each** of the following.

| (i) a co-ordinate bond | (ii) a covalent bond | (iii) a lone pair |
|------------------------|----------------------|-------------------|
|                        |                      |                   |

(June 2010 P21)

Q6 Copper, proton number 29, and argon, proton number 18, are elements which have different physical and chemical properties. In the solid state, each element has the same face-centred cubic crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, anions or cations. In the diagram above, the particles present are represented by  $\bullet$ .

(a) Which types of particle are present in the copper and argon crystals? In each case, give their formula.

| element | particle | formula |
|---------|----------|---------|
| copper  |          |         |
| argon   |          |         |

At room temperature, copper is a solid while argon is a gas.

(b) Explain these observations in terms of the forces present in **each** solid structure.

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(June 2010 P22)

Q7 The boiling points of these two compounds are given below.

| compound                        | BP/K  |
|---------------------------------|-------|
| CH <sub>3</sub> CH <sub>3</sub> | 184.5 |
| CH <sub>3</sub> F               | 194.7 |

Suggest explanations for the following.

(i) the close similarity of the boiling points of the two compounds

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(ii) the slightly higher boiling point of  $\text{CH}_3\text{F}$

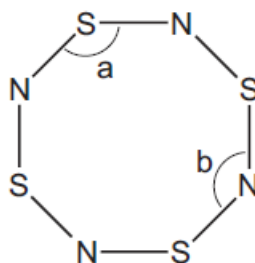
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(June 2011 P23)

Q8 Sulfur forms the compound  $\text{S}_4\text{N}_4$  with nitrogen. The structure of  $\text{S}_4\text{N}_4$  is shown below.

Assume all bonds shown are single bonds.



(i) Determine the number of lone pairs of electrons around a nitrogen atom and a sulfur atom in  $\text{S}_4\text{N}_4$ .

nitrogen atom ..... sulfur atom .....

(ii) Which bond angle, a or b, in the  $\text{S}_4\text{N}_4$  molecule will be smaller? Explain your answer.

.....

.....

(June 2012 P22)

Q9 Carbon disulphide,  $\text{CS}_2$ , is a volatile, stinking liquid which is used to manufacture viscose rayon and cellophane.

(a) The carbon atom is in the centre of the  $\text{CS}_2$  molecule. Draw a 'dot-and-cross' diagram of the carbon disulphide molecule. Show outer electrons only.

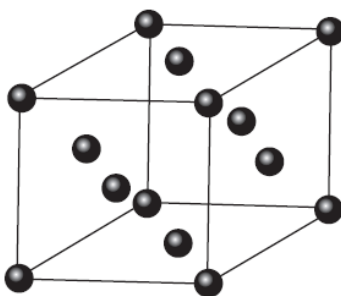
(b) Suggest the shape of the molecule and give its bond angle.

shape .....

bond angle .....

(Nov 2005)

Q10 Copper and iodine are both solids which have different physical and chemical properties. Each element has the same face-centred crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, anions or cations. In the diagram above, the particles present are represented by a black circle.

**(a)** Which type of particles are present in the iodine crystal? Give their formula.

particle ..... formula .....

**(b)** When separate samples of copper or iodine are heated to 50 °C, the copper remains as a solid while the iodine turns into a vapour.

**(i)** Explain, in terms of the forces present in the solid structure, why copper remains a solid at 50 °C.

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**(ii)** Explain, in terms of the forces present in the solid structure, why iodine turns into a vapour when heated to 50°C.

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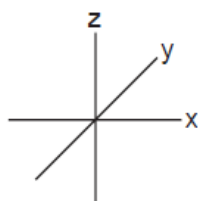
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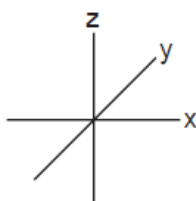
(Nov 2006)

Q11 This question is about the bonding of covalent compounds.

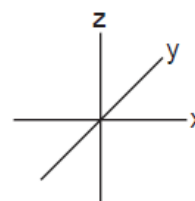
**(a)** On the axes below, sketch the shapes of a 1s, a 2s, and a 2p<sub>x</sub> orbital.



1s



2s



2p<sub>x</sub>

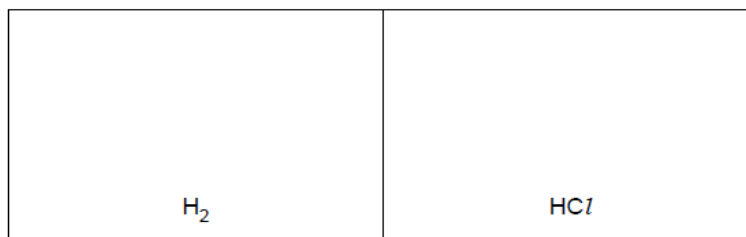
**(b)** Covalent bonding occurs when two atoms share a pair of electrons. Covalent bonding may also be described in terms of orbital overlap with the formation of sigma bonds.

**(i)** How are the two atoms in a covalent bond held together? In your answer, state which particles are attracted to one another and the nature of the force of attraction.

.....

.....

(ii) Draw sketches to show orbital overlap that produces the  $H_2$  and bonding in the  $HCl$  molecules.



(c) The bond in the  $HCl$  molecule is said to be 'polar'.

(i) What is meant by the term *bond polarity*?

(ii) Explain why the  $HCl$  molecule is polar.

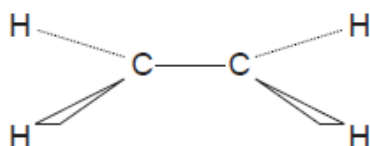
(d) The bonding in ethene may be described as a mixture of  and  bonding.

Each carbon atom in ethene forms three

bonds as shown below.

On the diagram, sketch the

bond that is also present in ethene.



(Nov 2007)

Q12(a) Briefly explain, in terms of the chemical bonds and intermolecular forces present in **each** compound, why  $CO_2$  is a gas and  $SiO_2$  is a solid at room temperature.

(b) Draw a simple diagram to show the structure of  $SiO_2$ . Your diagram should contain at least **two** silicon atoms **and** show clearly how many bonds each atom forms.

(Nov 2009 P22)