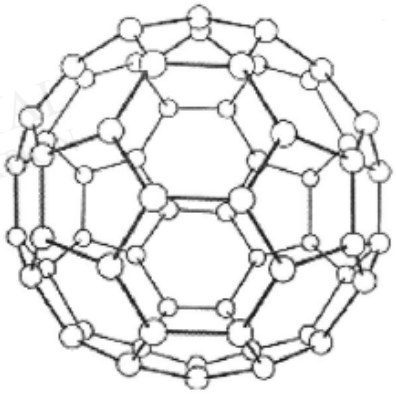
O Level Pure Chemistry Structured

Chemical Bonding Test 2.0

Q1

Until 1985 chemists believed that there were only two allotropes of carbon. In 1985 a third allotrope, buckminsterfullerene, was identified. The diagram shows the structure of a molecule of buckminsterfullerene. Each circle represents one carbon atom.



The molecule has 60 carbon atoms covalently bonded together, to give a structure with a shape similar to a modern football.

(a) Name the other two allotropes of carbon.

.....[1]

(b) (i) Suggest the formula of buckminsterfullerene.

.....[1]

(ii) Calculate the number of moles of buckminsterfullerene in 3600 g of the substance.

[2]

(iii) Suggest, in terms of structure and bonding, why buckminsterfullerene might be expected to vapourise at a much lower temperature than the other allotropes of carbon named in **(a) (ii)**.

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.....[3]

Q2

Some physical properties of chlorides of carbon and lead are shown in the table below.

chloride	melting point/°C	electrical conductivity
tetrachloromethane, CCl_4	-23	does not conduct in any state
lead(II) chloride, $PbCl_2$	498	good conductor in molten state but non-conductor in aqueous solution

(a) Draw a 'dot and cross' diagram to show the bonding in tetrachloromethane
Show outer electrons only.

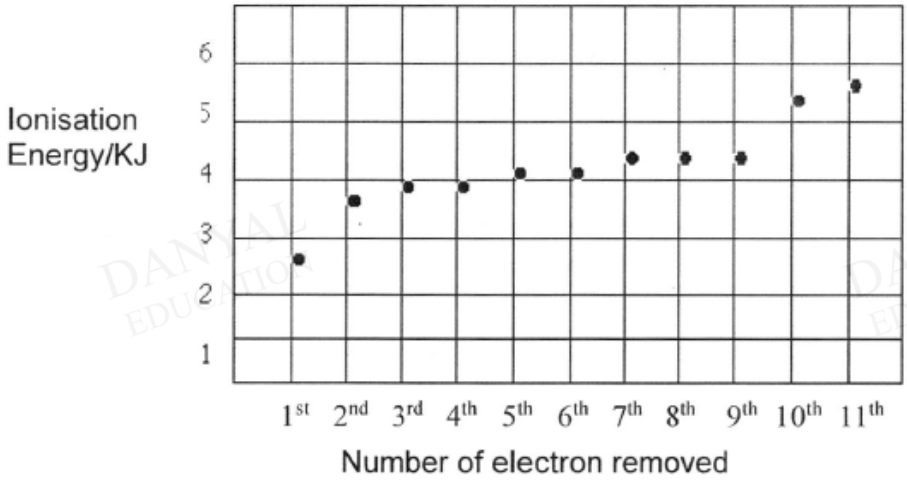
[1]

(b) Explain why tetrachloromethane and lead(II) chloride have different properties.

[4]

Q3

(a) The ionization energy of an atom describes the minimum amount of energy required to remove an electron (to infinity) from an atom.
The data below shows a plot of ionisation energy against the number of the electron removed for sodium.



Use the information above to explain the trend in ionisation energy for sodium with reference to its electronic structure. [3]

(b) The table below shows the first ionization energy (energy required to remove the first electron from the atom) of elements in Period 3.

element	Na	Mg	Al	Si	P	S	Cl	Ar
first ionisation energy/ kJ /mol	496	738	577	786	1060	1000	1256	1520
formula of the hydride of the element	NaH	MgH_2	AlH_3			H_2S	HCl	

(i) Complete the table above by filling in the formulae of the 2 hydrides. [1]

(ii) Explain why there is a great difference in the first ionization energy of sodium and argon. [2]

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(iii) Draw a 'dot and cross' diagram to show the bonding in sodium hydride. You need to show **all** the electrons. [2]

(iv) Suggest one similarity and one difference in physical property between sodium hydride and hydrogen chloride. [2]

Similarity:_____

_____

_____

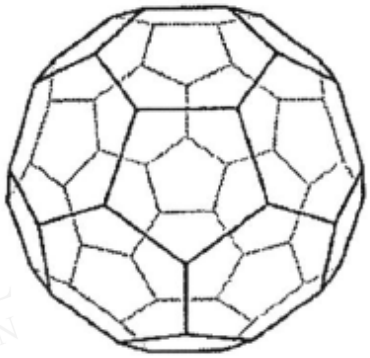
Difference:_____

_____

_____

Q4

In 1985 the fullerenes were discovered. They are solid forms of the element carbon. The structure of the C_{60} fullerene, the smallest fullerene, is given below.



(a) Another fullerene has a relative molecular mass of 840.
How many carbon atoms are there in one molecule of this fullerene?

.....[1]

(b) Fullerenes are soluble in liquid hydrocarbons such as octane. The other solid forms of carbon are insoluble.

Describe how you could obtain crystals of fullerenes from soot which is a mixture of fullerenes and other solid forms of carbon.

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.....[3]

(c) Each carbon atom in C_{60} fullerene is bonded to 3 other carbon atoms, which is similar to that in graphite.

(i) Explain why graphite is able to conduct electricity.

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.....[1]

(ii) Suggest why C_{60} fullerene is unable to conduct electricity.

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.....[1]

Q5

Elements that tend to gain electrons are said to be electronegative. Electronegativity is a measure of how strongly an atom of that element attracts electrons when it is bonded with atoms of other elements. It is a number between 0 and 4.0. A covalent bond is formed between two atoms if the difference in their electronegativities is small (usually less than 1.5). An ionic bond is formed between two atoms if the difference in their electronegativities is large (usually more than 1.5).

Table 8.1 shows the electronegativities of the first twenty elements.

symbol	atomic number	electronegativity	symbol	atomic number	electronegativity
H	1	2.1	Na	11	0.9
He	2	0	Mg	12	1.2
Li	3	1.0	Al	13	1.5
Be	4	1.5	Si	14	1.8
B	5	2.0	P	15	2.1
C	6	2.5	S	16	2.5
N	7	3.0	Cl	17	3.0
O	8	3.5	Ar	18	0
F	9	4.0	K	19	0.8
Ne	10	0	Ca	20	1.0

Table 8.1

(a) Describe the trend seen in the electronegativity of the elements going across the Periodic Table, from left to right.

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.....[1]

(b) Sodium forms the compound, sodium chloride, with chlorine. Using ideas about electronegativity, explain why sodium chloride is an ionic compound.

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.....[1]

(c) Boron reacts with hydrogen to form the compound boron hydride, BH_3.

(i) Using ideas about electronegativity, predict the type of bond formed between boron and hydrogen.

.....[1]

(ii) Draw a 'dot-and-cross' diagram to show the type of bonding involved. You only need to show valence electrons.

[2]

(iii) Describe why the bonding formed in boron hydride is unusual.

.....

.....[1]

(d) When two atoms form a bond, the distance between the nuclei of the two atoms can be measured. This is the bond length. Table 8.2 shows the bond lengths of the covalent bonds formed between carbon atoms and halogen atoms.

covalent bond	C – Cl	C – Br	C – I
bond length / nm	0.177	0.193	0.214

Table 8.2

Two students, Tom and Jerry, made the following conclusions when shown the data in Table 8.2.

Tom: "A more reactive halogen will form a covalent bond with a shorter bond length with carbon."

Jerry: "The greater the difference in electronegativity between carbon atom and the halogen atom, the shorter is the bond length."

Comment on what Tom and Jerry had concluded. Make use of the information available in Table 8.1 and Table 8.2 to support your answer.

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.....[3]

Answers

Chemical Bonding Test 2.0

Q1

3a	diamond and graphite [both answers must be correct to score1 m]	1
b i	C_{60}	1
ii	Mr = 12 x60 = 720 [1] no. of moles of bunkminsterfullerene = mass/Mr = 3600/720 = 5 mol [1] [allow e.c.f. from b i]	2
iii	Diamond and graphite are both giant molecular structure whereas buckminsterfullerene has a simple molecular structure. [1]	3
	More energy is required to break the strong covalent bonds between the carbon atoms throughout the giant structure [1] than overcoming the weak intermolecular forces of attraction between the simple buckminsterfullerene molecules. [1]	

Q2

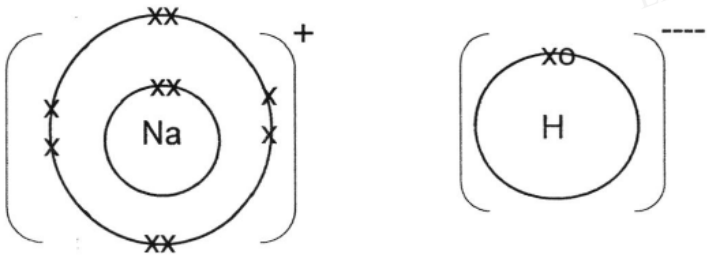
(a) Non bonded electrons [;]
Bonded electrons [;] [1]

(b) Electrical conductivity:
Tetrachloromethane molecules are electrically neutral. There are no mobile ions and electrons to conduct electricity.[1] [4]

Whereas lead(II) chloride is insoluble in water and hence ions are held in fixed position and are not mobile[;]
Pb^{2+} and Cl^- ions are mobile in aqueous solution that can act as charged carriers.[;]
2; - 1

Melting point:
Tetrachloromethane has a simple molecular structure consisting of molecules held by weak intermolecular forces of attraction. [;]
Lead (II) chloride has a giant ionic lattice structure consisting of oppositely charged ions held by strong electrostatic forces of attraction. [;]
A larger amount of energy is required to overcome the forces in lead (II) chloride. [;]
3; [2]

Q3

a		Increase in ionisation energy [1] Decreasing Distance/shell [1] Increasing charge [1]	3
b	i	Formula of the hydride of the element: ----- SiH4 PH3 ----- 0.5 mark each	1
	ii	3rd shell same [0.5]; decreasing atomic radius [0.5]; closer nucleus and electron [0.5]; stronger electrostatic force of attraction for argon [0.5]	2
	iii	 sodium hydride	2
	iv	Similarity: NaH and HCl are both soluble in water.c [1] Difference: NaH has high melting point and boiling point/solid HCl has low melting and boiling point/gas [1] Must have correct comparison to earn the mark	2

Q4

a) 70;
b)
Add octane (or other liquid hydrocarbon) (to soot);
COND(on addition of any solvent) filter (to remove insoluble forms of carbon);
(allow to) evaporate or heat or warm or leave in sun(to get crystals of fullerene);
c)
(i) delocalised electrons/free electrons/sea of electrons [1]
COND (on electrons) move/mobile/electrons flow [1]
(ii) the delocalised electrons can only move within the molecules, but not between molecules;

Q5

(a) The electronegativity of the elements <u>increases</u> until at the noble gases where it <u>drops to zero</u>.

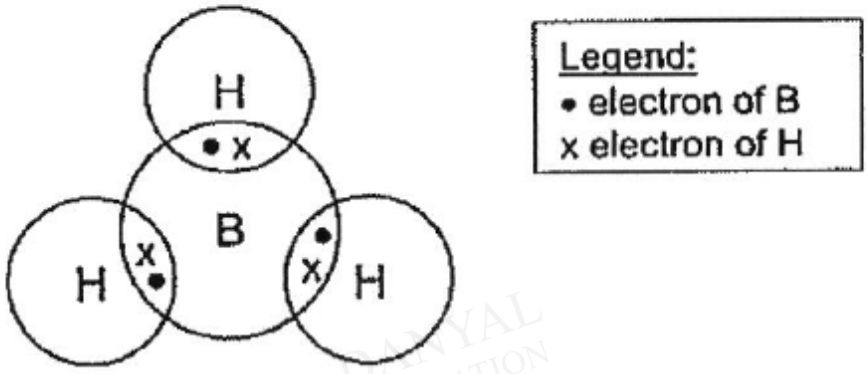
Both underlined points must be mentioned in order to score.

(b) The difference in electronegativity between sodium and chlorine is <u>2.1</u> which is <u>greater than 1.5</u>.

Must make use of the information in the table.

(c) **(i)** covalent

(ii)



Electrons involved in bonding are drawn correctly – [1]
No other valence electrons are drawn – [1]
Deduct [½] if legend is not given.

(iii) There are only <u>6 electrons</u> in the valence shell of boron after bonding when it is usually <u>8 electrons</u>.

Must be able to compare 6 electrons against 8.

or

After bonding, boron has not attained the electronic configuration of a noble gas.

(e) Tom is correct.
No marks awarded.

Chlorine is the most reactive of the three elements. The length of the C – C*l* bond is the shortest. / Iodine is the least reactive of the three elements. The length of the C – I bond is the longest. [1]

Jerry is also correct.
No marks awarded.

The difference in electronegativity between carbon and fluorine is 1.5, and that between carbon and chlorine is 0.5. [1 mk pt] Thus, it can be deduced that the difference in electronegativity between carbon atom and halogen atom decreases down Group VII. [1 mk pt]

or

Comparing the electronegativity of fluorine and chlorine, it can be seen that electronegativity decreases down Group VII. [1 mk pt] Thus, it can be deduced that the difference in electronegativity between carbon atom and halogen atom decreases down Group VII. [1 mk pt]

Thus, the difference in electronegativity is the greatest between carbon atom and chlorine atom compared to carbon atom and the other halogens (bromine and iodine) and the length of the C – C*l* bond is the shortest. [1 mk pt]

3 mk pts – [2]
1-2 mk pts – [1]