ATOMIC STRUCTURE

pre-test

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1. What are the charges and masses of the following subatomic particles?

	Relative charge	Relative mass
proton		
neutron		
electron		

2. Element **A** has an electronic structure 2,8,7.
   Element **B** has an electronic structure 2,8,2.
   What is the type and formula of the compound formed by **A** and **B**?

	type of compound	formula
A	covalent	A_2B
B	covalent	AB_2
C	ionic	A_2B
D	ionic	AB_2

3. Which particle contains the same number of neutrons and electrons?

A $^{16}_{8}O^{2-}$ **B** $^{12}_{6}C$

C $^{39}_{19}K^{+}$ **D** $^{40}_{20}Ca^{2+}$

4. Complete Table 1.1 to show the electronic configuration of four particles, **X**, $\mathbf{X^{2+}}$, $\mathbf{Y^{-}}$ and $\mathbf{Z^{2-}}$.

Table 1.1

Particle	Number of protons	Number of electrons	Electronic Configuration
X	20		
$\mathbf{X^{2+}}$			
$\mathbf{Y^{-}}$		18	
$\mathbf{Z^{2-}}$		10	

atoms

Everything that is matter, regardless of their state and material, is made up of atoms. The water you drink is formed of H_2O molecules, each consisting of H and O atoms. Similarly, the butter you spread on your toast is made up of fat molecules, which are primarily composed of C, H, and O atoms. Atoms combine in various ways to form things around us.

Atom: smallest unit of matter that retains the properties of an element, consists of a nucleus containing protons and neutrons, surrounded by electrons

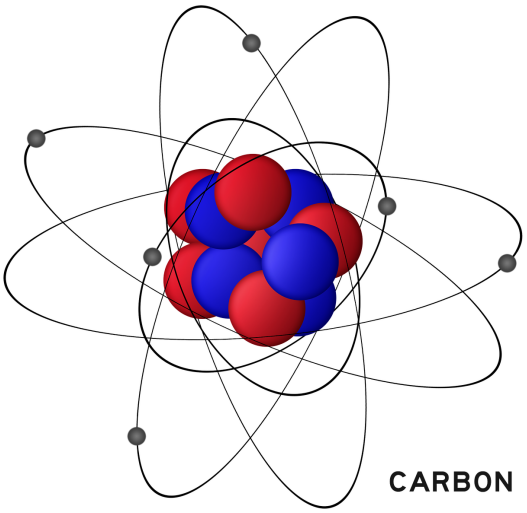
Element: a pure substance that consists entirely of one type of atom

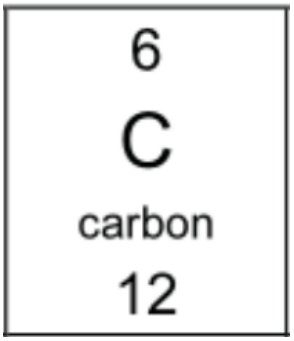
The Periodic Table of Elements (for O Level Chemistry 5070)

Group																	
I	II											III	IV	V	VI	VII	VIII
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9	Key: atomic number / atomic symbol / name / relative atomic mass										5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

subatomic particles





The three fundamental subatomic particles that comprise an atom are protons, neutrons, and electrons.

Located in the **nucleus** at the centre of the atom, protons and neutrons make up almost all of the atom's **mass**. Both of these particles are relatively heavy and have approximately the same mass, but protons possess a positive electric charge, while neutrons have no electric charge.

Surrounding the nucleus in a complex, cloud-like arrangement are the electrons, which are extremely light in comparison to the protons and neutrons. These electrons carry a negative electric charge.

The ……..….. determines the identity of an element while the …….. determine how they combine with other atoms to form molecules and compounds (chemical properties). In a neutral atom, the number of electrons is equal to the number of protons, ensuring an overall electrically balanced state.

	Relative charge	Relative mass
proton		
neutron		
electron		

Table 1.2 relative masses and relative charges of subatomic particles

KEY CONCEPTS

- The **charge** of an atom depends on the number of …… and the number of ……
- The **mass** of an atom depends on the number of …… and the number of ……
- Since the atom does not have a …….., the number of protons and electrons are the same.

isotopes

Isotopes are **<u>atoms of the same element</u>** with the same number of protons but different number of neutrons.

Isotopes have the *same* number of protons → same number of electrons → undergo the same chemical reactions to form compounds → same …… properties

Isotopes have *different* numbers of neutrons → different masses → different …… properties
e.g. mp, bp, density

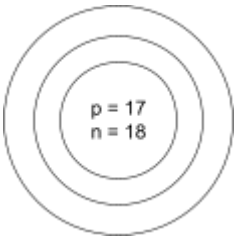
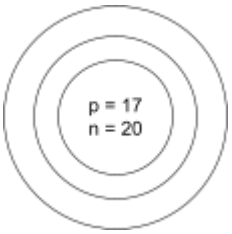
	
Chlorine - 35	Chlorine - 37

Figure 1.3 isotopes of chlorine

Chlorine exists as chlorine-35 and chlorine-37 atoms with the percentage abundances of 75% and 25% respectively. The final atomic mass seen on the periodic table is the sum of atomic mass/percentage abundance of all the isotopes of chlorine.

KEY CONCEPTS

- Define *isotopes* **!!!**
  Isotopes are atoms of the same element with the same number of protons but different number of neutrons
- Same chemical properties (the chemical reactions they undergo)
- Different physical properties (mp, bp, density)

Concept Check: Isotopes

Most of the carbon in nature is the isotope carbon-12. However, two other isotopes exist, carbon-13 and carbon-14. Complete the following table regarding the isotopes of carbon

	^{12}C	^{13}C	^{14}C
Mass Number, A			
Atomic number, Z			
Number of protons			
Number of electrons			
Number of neutrons			

concept check: atoms, subatomic particles and isotopes

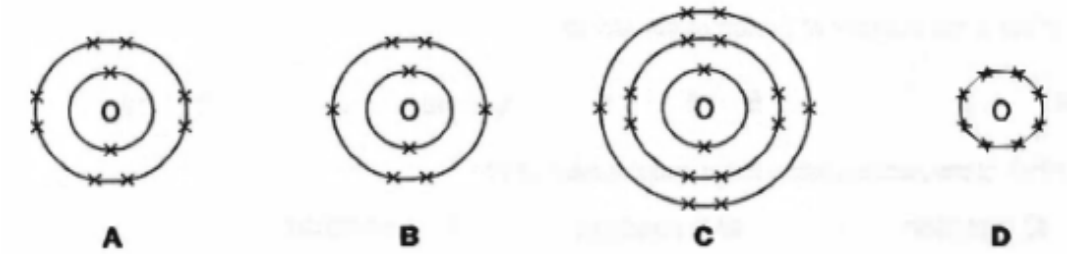
1. Which sub-atomic particles are found in the nucleus of an atom?

   A Electrons and neutrons
   B Electrons and protons
   C Protons
   D Protons and neutrons

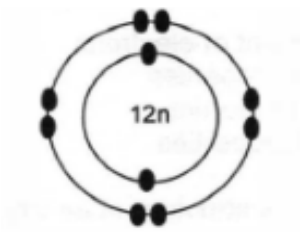
2. Which statement is not true about isotopes of an element?

   A They have the same arrangement of electrons.
   B They have the same chemical properties
   C They have the same number of protons.
   D They have the same physical properties.

3. Which diagram represents the electronic structure of an oxygen atom?



4. The diagram shows the electron arrangement and the number of neutron of an atom.



   What is the number of protons of the atom?
   A 2 **B** 8 **C** 10 **D** 12

5. Fill in the table with the relevant information for each atom

Element	Group	Number of protons	Number of electrons	Number of neutrons	Electronic Configuration
O					
N					
Mg					
Al					

ionic compounds

Atoms aim to achieve a **full shell configuration**. Atoms can achieve this stable configuration by either gaining or losing electrons, which results in the formation of ions.

- **Metal** atoms have one, two, or three electrons in their outermost shell may **lose** those electrons to achieve stability, forming positively charged ions, or cations.
- **Non-metal** atoms with five, six, or seven electrons in their outer shell may **gain** electrons to reach a stable configuration, forming negatively charged ions, or anions.

Through these interactions, atoms can achieve greater stability by filling their valence shell, mirroring the electron configurations of the noble gases, which are naturally stable elements.

Element	Group	Electronic Configuration	How can the atom achieve full shell config?	Ion it forms	Electronic configuration of ion
O	VI	2, 6			
N	V	2, 5			
Mg	II	2, 8, 2			
Al	III	2, 8, 3			

How atoms form ions

Draw the atoms and ions in the table below:

Na atom	**Na^+ ion**	**Cl atom**	**Cl^- ion**

ionic compounds: bonding

Ionic bonds are the strong electrostatic forces of attraction between a positively-charged metal cation and a negatively-charged non-metal anion.

- Ionic bonds are *always* strong
- Ionic bonds are between positively-charged and negatively-charged ions.

Draw the ionic compounds in the table below:

NaC*l* compound	**MgCl_2 compound**

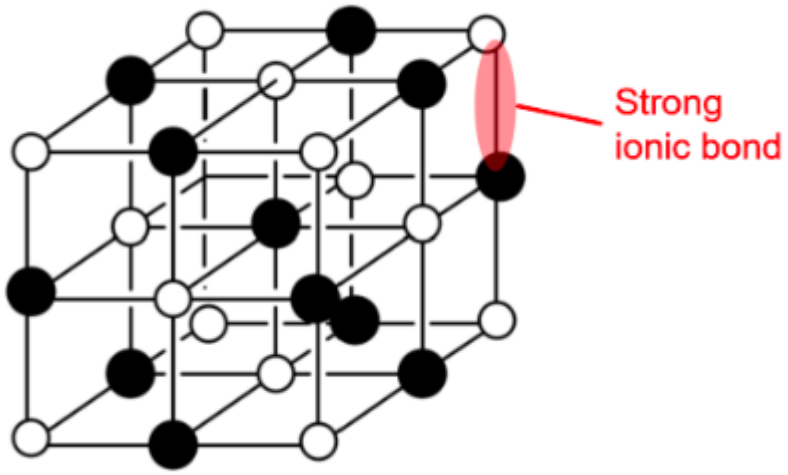
concept check: ionic bonds

State the ion that X and Y atoms can form. Then write the formula of the ionic compound.
Put a cross (X) in the column if X and Y will not form an ionic compound.

X atom	**X ion**	**Y**	**Y ion**	Formula of ionic compound (X) if it will not be formed
2,8,1		2,8,7		
2,8,2		2,6		
2,8,8,1		2,8,7		
2,8,8,2		2,8,7		
2,4		2,5		

ionic compounds: structure

Ionic compounds exist as giant ionic lattices in which the ions are held by electrostatic forces of attraction between ions.



Drawing of the ionic lattice structure is **not** required.

However, you should recognise that this particular structure shows that the ratio of the number of cations : the number of anions is 1:1.

So, the diagram on the left could be NaCl, MgO but unlikely to be $MgCl_2$

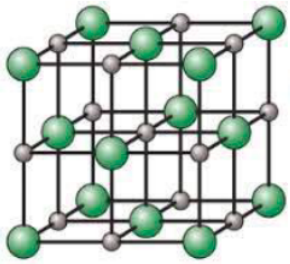
ionic compounds: properties

1. High melting and boiling points → what bonds are being overcome? strong or weak bonds?
2. Solubility in water
3. Ability to conduct electricity → any mobile charge carriers?
    a. No in the solid state
    b. Yes in the aqueous and molten states

Structure	NaCl is a ..... with
Bonding	Strong electrostatic forces of attraction between the …….. and ……..
High m.p. / b.p. > 1000 °C	The **ionic bonds** between the ions are strong and require a lot of energy to overcome, causing the mp and bp of NaCl to be high.
Soluble in water	Highly soluble in water to form ions (explanation not required) Ionic compounds are soluble in water because the partially charged (polar) water molecules can attract the ions, causing disruption to the ionic lattice structure. This results in the ions separating and dissolving in the solution.
Unable to conduct electricity in the solid state	In the solid state, the Na+ and Cl- ions are held in fixed positions in the giant ionic lattice. No free moving ions or electrons are available to act as mobile charge carriers to conduct electricity.
Able to conduct electricity in aqueous and liquid state	In the aqueous / liquid state, Na+ and Cl- ions move freely throughout the liquid and act as mobile charge carriers to conduct electricity.

concept check: properties of ionic compounds

1. The diagram shows the arrangement of ions in an ionic crystal.



Which compound cannot have this arrangement of ions?

A lithium nitrate
B zinc sulfate
C sodium oxide
D lead (II) sulfate

2. Element **A** has an electronic structure 2,8,7.
Element **B** has an electronic structure 2,8,2.
What is the type and formula of the compound formed by **A** and **B**?

	type of compound	formula
A	covalent	A_2B
B	covalent	AB_2
C	ionic	A_2B
D	ionic	AB_2

3. Which particle contains the same number of neutrons and electrons?

A $^{16}_{8}O^{2-}$ **B** $^{12}_{6}C$

C $^{39}_{19}K^{+}$ **D** $^{40}_{20}Ca^{2+}$

4. Complete the table below to show the electronic configuration of **X**, $\mathbf{X^{2+}}$, $\mathbf{Y^{-}}$ and $\mathbf{Z^{2-}}$.

Particle	Number of protons	Number of electrons	Electronic Configuration
X	20		
$\mathbf{X^{2+}}$			
$\mathbf{Y^{-}}$		18	
$\mathbf{Z^{2-}}$		10	

5. Using structure and bonding, explain why NaCl has a high boiling point.

   NaCl has a …… structure with strong …….. ……. between ……. and ……. Since the ionic bonds are strong and require a lot of energy to overcome, NaCl has a high boiling point.

6. Using structure and bonding, explain why MgO is unable to conduct electricity in the solid state but able to conduct electricity in the aqueous and liquid states.

   ……

   ……

   ……

   ……

covalent compounds

A covalent bond is a type of chemical bond formed when atoms share one or more pairs of electrons.

- Between **atoms** of non-metals (right side of the staircase)
- Covalent bonds are always **strong**: strong attraction between the positive nucleus of one atom and the shared electrons
- In one covalent bond between two atoms, every atom contributes one electron.
  In a double covalent bond, every atom contributes one electron for each covalent bond, total 2 each.
- To determine how many bonds an atom likes to form, look at the valency of the atom.

O_2	N_2

CO_2	NH_3
CH_4	H_2O

covalent compounds: bonding

Here there are 2 types of bonding / forces of attraction. PLEASE make sure you are clear on their differences.

BETWEEN ATOMS, there are …….. formed by the sharing of electrons by atoms. Covalent bonds are broken during **decomposition** and not during change of state processes.

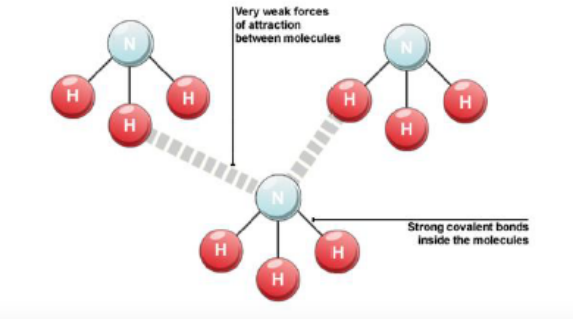
BETWEEN MOLECULES, there are weak ……..
……. that attract molecules to each other due to their various interactions.

Intemolecular forces of attraction are affected by the **size of the molecule.** When the molecule is larger, the size of the molecule increases.

Intermolecular forces are broken during **change of state processes.**

covalent compounds: structure

Covalent compounds exist as simple molecules (in your syllabus) with strong covalent bonds between atoms and weak imfoa between molecules.



covalent compounds: properties

1. Low melting and boiling points → what bonds are being overcome? strong or weak bonds?
2. Solubility in water
3. Unable to conduct electricity in all states → any mobile charge carriers?

Structure	CO_2 has a simple molecular structure
Bonding	With strong covalent bonds between C and O **atoms** but weak intermolecular forces of attraction between CO_2 **molecules**.
Low m.p. / b.p.	As the **intermolecular forces** between CO_2 molecules are weak and require little energy to overcome, the mp and bp of CO_2 is low.
Soluble in water	Insoluble in water (explanation not required)
Unable to conduct electricity in all states	**Electrons are in fixed positions** so there are no free moving electrons or ions to act as mobile charge carriers to conduct electricity.

STRENGTH OF INTERMOLECULAR FORCES

As the size of the molecule increases, the strength of the intermolecular forces of attraction generally increases.

For example, substances with longer hydrocarbon chains, such as octane (C_8H_{18}), have higher boiling points compared to those with shorter chains, like methane (CH_4). This correlation between molecular size and force strength can have a direct impact on various properties of the material, such as its boiling or melting points and viscosity.

concept check: properties of covalent compounds

1. When sucrose is heated, it melts at 192 °C. At this temperature it starts to decompose, and the liquid sucrose turns dark brown.

   Which conclusion is correct?
   A the covalent bonds are stronger than the intermolecular forces
   B the intermolecular forces, and some covalent bonds, are about the same strength
   C the intermolecular forces are stronger than the covalent bonds
   D the structure of the solid is a lattice structure

2. Chloride forms various oxides. The formulae and boiling point of two such oxides are given below.

name	formula	boiling point / °C
dichlorine monoxide	Cl_2O	2
dichlorine hexoxide	Cl_2O_6	200

   (a) Draw a 'dot-and-cross' diagram for dichlorine monoxide.

   [2]

   (b) Suggest a reason for the difference in the boiling points of the two compounds.

   ……

   ……

   …… [2]

   (c) Predict and explain the difference in electrical conductivities of molten magnesium oxide and liquid dichlorine monoxide, in terms of structure and bonding.

   ……

   ……

   …… [2]

prelim question drills: atomic structure and bonding MCQ

1. ^{85}Z and ^{87}Z are isotopes of element Z.

   How is the ion formed by ^{85}Z different from the ion formed by ^{87}Z?

   A it has two less neutrons and two less electrons
   B it has two less neutrons but no less electrons
   C it has two less protons and two less electrons
   D it has two less protons but no less electrons

2. The symbol for an atom of boron is ${}^{11}_{5}B$.

   What does the number 11 represent for an atom of boron?
   A the number of protons
   B its position in the Periodic Table
   C the total number of protons, neutrons, and electrons
   D the nucleon number

3. Element Y has the electronic configuration 2, 2.

   Element Z has the electronic configuration 2, 8, 7.

   What is the formula of the compound formed between Y and Z?

   A YZ
   B YZ_2
   C Y_2Z
   D Y_3Z_2

4. What is the total number of elements present in one unit of wolframite, $(FeMn)WO_4$?

   A 3
   B 4
   C 7
   D 9

5. Four atoms are shown.

   ${}^{14}_{6}C$ ${}^{15}_{7}N$ ${}^{16}_{8}O$ ${}^{17}_{9}F$

   Which statement about all four atoms is correct?

   A They have the same number of electrons.
   B They have the same number of neutrons.

C They have the same number of nucleons.
D They have the same number of protons.

6. The relative atomic mass of chlorine is 35'5-
What is the mass of 2 moles of chlorine gas?

A 17.75 g **B** 71 g

C 35.5 g **D** 142 g

7. Which of the following statements is true about subatomic particles in an atom?

A A neutron has a relative mass of 1.
B All atoms have protons, neutrons and electrons.
C An electron has a relative charge of 1+.
D Protons are found orbiting around the nucleus.

8. Atom E has an electronic configuration of 2.8.3.
Atom F has an electronic configuration of 2.6.
Which row correctly describes the compound formed between E and F?

	bonding	**melting point**
A	covalent	low
B	covalent	high
C	ionic	low
D	ionic	high

9. Atoms W and X are isotopes.
W has 35 protons and 46 neutrons.
Which of the following shows the correct symbol for X?

A $^{35}_{46}X$ **B** $^{46}_{35}X$

C $^{79}_{35}X$ **D** $^{81}_{35}X$

10. Which of the following ions does not have the electronic configuration of an argon atom?

A Ca^{2+}

B Cl^-

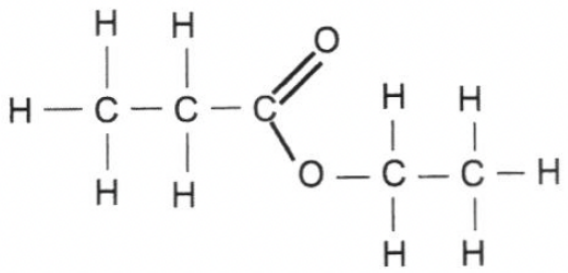
C K^+

D O^{2-}

11. Which statement about isotopes is correct?

A They have different numbers of electrons but the same number of protons.
B They have different numbers of electrons shells but the same number of neutrons.
C They have different numbers of neutrons but the same number of electron shells.
D They have different numbers of protons but the same number of electrons.

12. The diagram shows the molecule ethyl propanoate.



A 7

B 13

C 16

D 17

13. An element X forms an ion X^{2-}
Which group of the Periodic Table is this element found in?

A Group I

B Group II

C Group VI

D Group VII

14. The chemical formula of the compound formed by P and Q is PQ_2.

Both P and Q are non-metals.

What is the correct electronic configuration of P and Q?

	P	Q
A	2.2	2.7

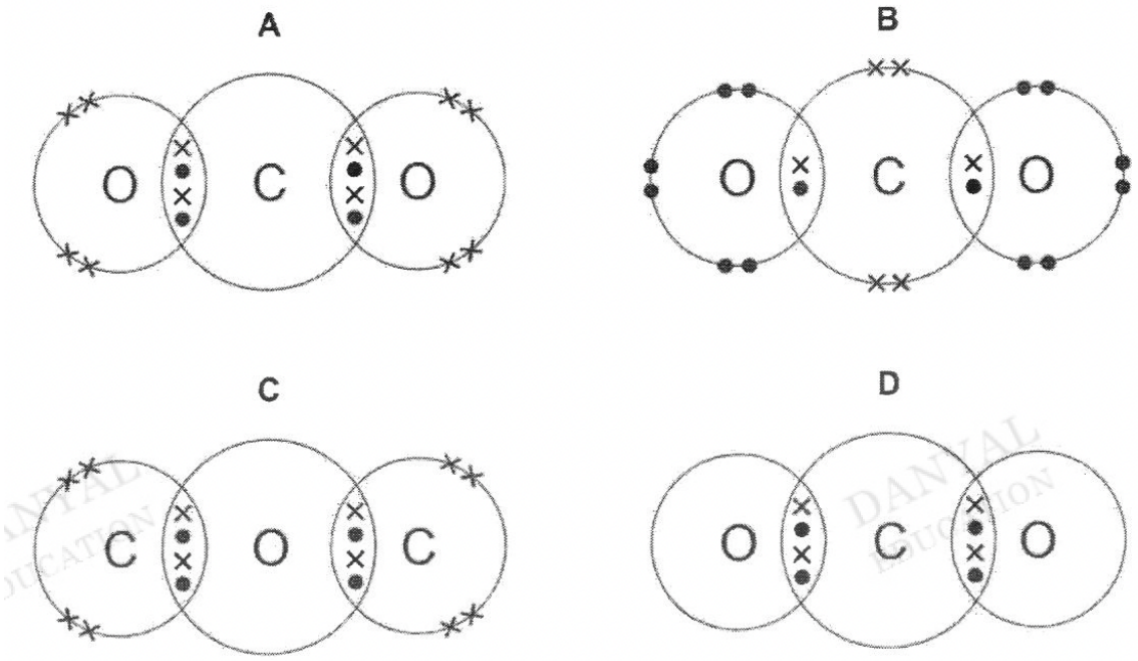
B	2.4	2.6
C	2.8.1	2.6
D	2.8.6	2.1

15. Potassium chlorate has the formula KC/O_3.
What is the chemical formula of copper(II) chlorate?

A CuC/O_3.
B Cu_2C/O_3.
C $Cu_3(C/O_3)_2$.
D $Cu(C/O_3)_2$

16. The bonding in a molecule of carbon dioxide can be represented by a 'dot-and-cross' diagram'

Which diagram is correct?



paper 2: atomic structure and bonding

1. Group VII contains halogens such as fluorine, chlorine, bromine and iodine.

   (a) Table 8.1 shows the number of electrons, neutrons and protons in two halogen particles. Complete the table below.

	number of electrons	number of neutrons	number of protons
$^{35}_{17}Cl$	17		
$^{79}_{35}Br^-$		44	

[3]

   (b) Three unknown halogens, X_2, Y_2 and Z_2, were given in an experiment.
   To identify the three given halogens, some tests were carried out.

      (i) Table 8.2 shows data about the melting and boiling points of one of the halogens X_2

halogen	melting point / °C	boiling point / °C
Z_2	–7.2	58.8

Table 8.2

      State the physical state of Z_2 at room temperature

      …… [1]

2. Carbon disulfide, CS_2, is a simple covalent compound used in manufacturing polymers and fibres.

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

[2]

   (b) Using your understanding of bonding and structure, which of these statements would you predict to be true and which would you predict to be false?

   Put a tick in one box in each row. [2]

	true	false
Carbon disulfide has a low boiling point.		
Carbon disulfide has good electrical conductivity when molten.		
Carbon disulfide is very soluble in water.		
Carbon disulfide is a crystalline solid at room temperature.		

3. Fig. 2.1 shows the electronic structures of lithium and fluorine atoms.

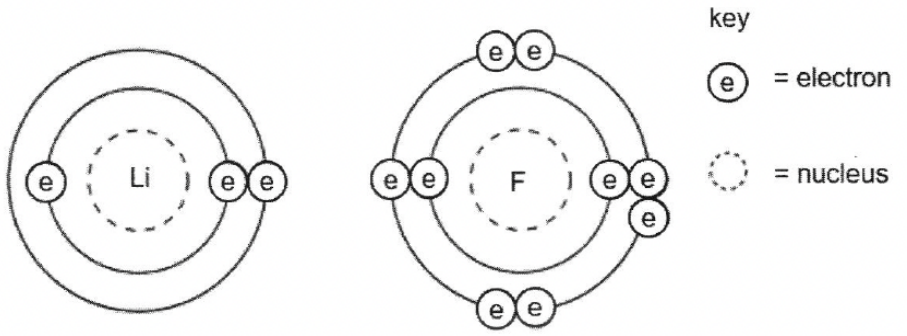


Fig. 2.1

(a) Fluorine reacts with lithium to form solid lithium fluoride.
Draw a 'dot and cross' diagram to show the bonding in lithium fluoride.
Show only the outer shell electrons.

(b) Using structure and bonding, explain why

(i) both solid lithium fluoride and solid Q do not conduct electricity.

……

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(ii) molten lithium fluoride will conduct electricity.

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