Mastering Chemistry

Book 1B

Topic 2 Microscopic World I

Content

Content

8.1 Covalent bonds (p. 110)

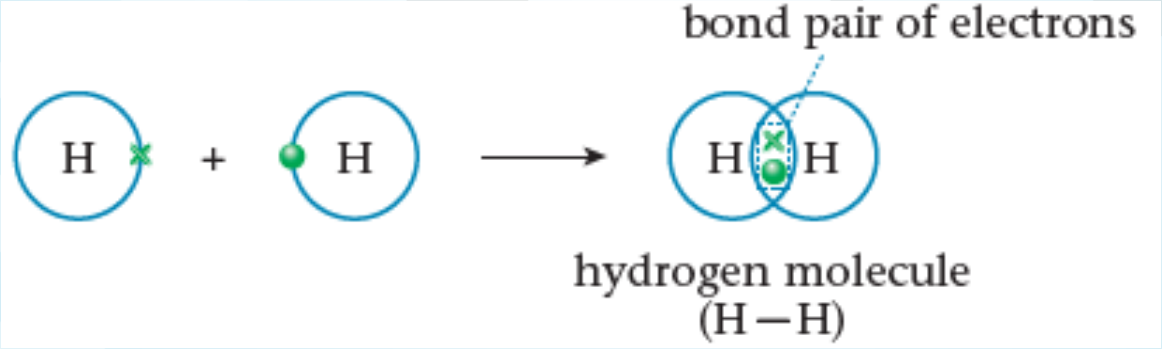
- When two atoms of non-metals combine, both need electrons so as to obtain a stable electronic arrangement. They manage this by sharing electrons. The bond formed is called a **covalent bond (共價鍵)**.
- In most of the cases, a **molecule (分子)** forms when two or more atoms are joined by covalent bonds.

Covalent bond *Ref.*

8.2 Covalent bonding in non-metals (p. 110)

Hydrogen

- Each hydrogen atom has one electron. It needs one more electron to obtain the electronic arrangement of a helium atom (2). To do this, two hydrogen atoms share a pair of electrons. This allows each atom to get the electronic arrangement of a helium atom.



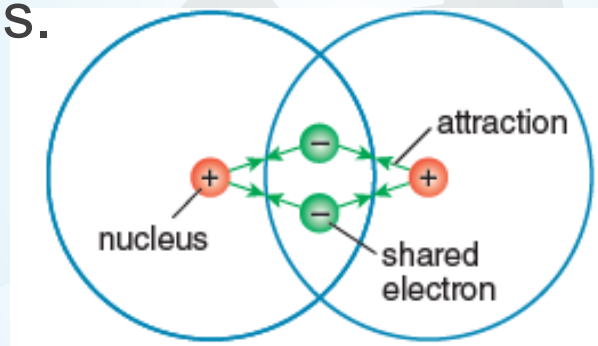
The covalent bond in a hydrogen molecule

A covalent bond forms when two atoms share a pair of electrons.

8.2 Covalent bonding in non-metals (p. 111)

Hydrogen

- The two hydrogen atoms in a molecule are held together by the strong electrostatic forces of attraction between their positively charged nuclei and the negatively charged shared electrons.



Electrostatic forces of attraction exist between the positively charged nuclei and the negatively charged shared electrons

A covalent bond is the electrostatic forces of attraction between the positively charged nuclei of the two bonded atoms and the negatively charged shared electrons.

8.2 Covalent bonding in non-metals (p. 111)

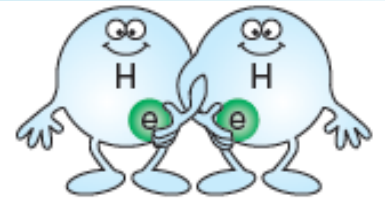
Hydrogen

- A covalent bond is **directional (有方向性)**, acting solely between the two atoms involved in the bond.
- One pair of shared electrons, or one **bond pair of electrons (鍵合電子對)**, makes a single covalent bond. The single covalent bond between the two hydrogen atoms can be represented by a single line as H–H.

8.2 Covalent bonding in non-metals (p. 111)

Hydrogen

- Two hydrogen atoms bond together to make a hydrogen molecule. This is called a **diatomic molecule (雙原子分子)**. The chemical formula of hydrogen gas is H_2.



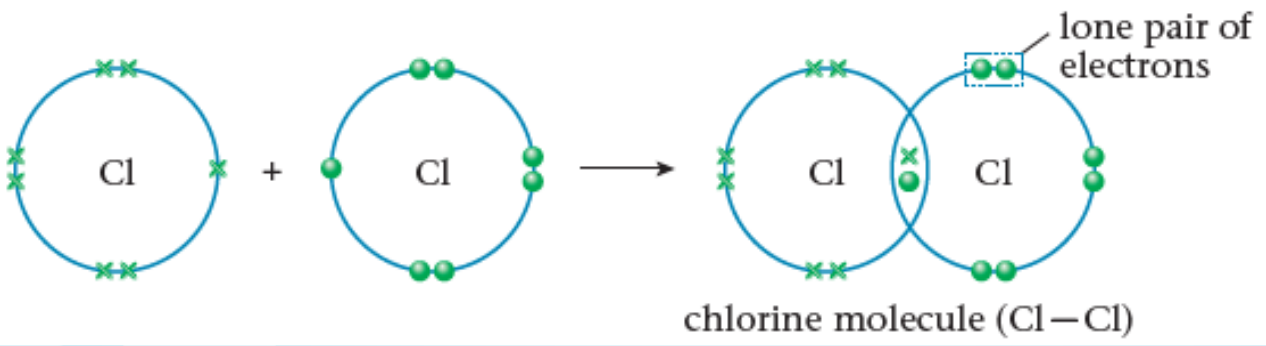
Two hydrogen atoms bond together to make a hydrogen molecule

- The chemical formula of a substance made up of molecules is also called its **molecular formula (分子式)**.
- The molecular formula of a substance gives the total number of atoms of each element present in a molecule of the substance.

8.2 Covalent bonding in non-metals (p. 112)

Chlorine

- A chlorine atom has an electronic arrangement of 2,8,7. Two chlorine atoms share a pair of electrons in their outermost shells to make a chlorine molecule (Cl_2). Now, each of the atoms gets the electronic arrangement of an argon atom (2,8,8).



Formation of a covalent bond in a chlorine molecule (only electrons in the outermost shells are shown)

8.2 Covalent bonding in non-metals (p. 112)

Chlorine

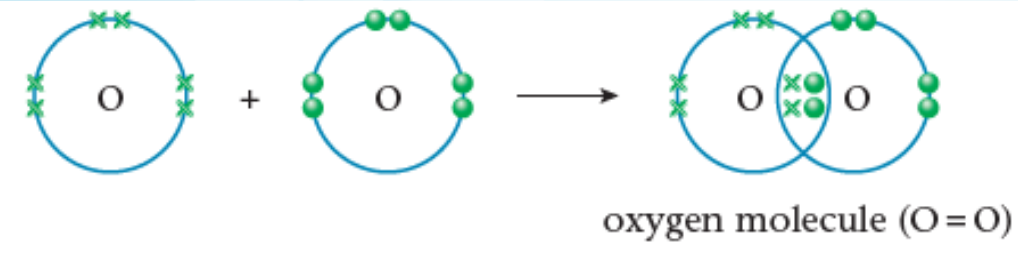
- The single covalent bond between the two chlorine atoms can be represented by a single line as Cl–Cl.
- In a chlorine molecule, the outermost shell of each atom contains three pairs of electrons that are not involved in the bonding. Chemists call these **lone pair of electrons (孤電子對)**.

A lone pair of electrons is a pair of electrons in the outermost shell of one of the atoms in a molecule which is not involved in bonding.

8.2 Covalent bonding in non-metals (p. 112)

Oxygen

- It is possible for two atoms to share more than one pair of electrons.
- An oxygen atom has an electronic arrangement of 2,6. Two oxygen atoms share two pairs of electrons in their outermost shells to make an oxygen molecule (O_2). Now, each of the atoms gets the electronic arrangement of a neon atom (2,8).



Formation of covalent bonds in an oxygen molecule (only electrons in the outermost shells are shown)

8.2 Covalent bonding in non-metals (p. 112)

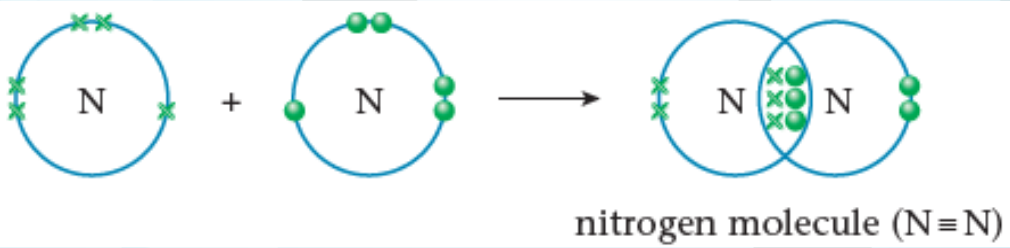
Oxygen

- A **double bond (雙鍵)** results when two pairs of electrons are shared between two atoms in a molecule.
- The double bond between the two oxygen atoms can be represented by two lines as O=O.

8.2 Covalent bonding in non-metals (p. 113)

Nitrogen

- A nitrogen atom has an electronic arrangement of 2,5. Two nitrogen atoms share three pairs of electrons in their outermost shells to make a nitrogen molecule (N_2). Now, each of the atoms gets the electronic arrangement of a neon atom (2,8).



Formation of covalent bonds in a nitrogen molecule (only electrons in the outermost shells are shown)

8.2 Covalent bonding in non-metals (p. 113)

Nitrogen

- A **triple bond (三鍵)** results when three pairs of electrons are shared.
- The triple bond between the two nitrogen atoms by triple lines as N≡N.

Covalent bonding in non-metals (p. 113)

Practice 8.1

1 Fluorine (atomic number 9) exists as diatomic molecules.

a) State the electronic arrangement of a fluorine atom.

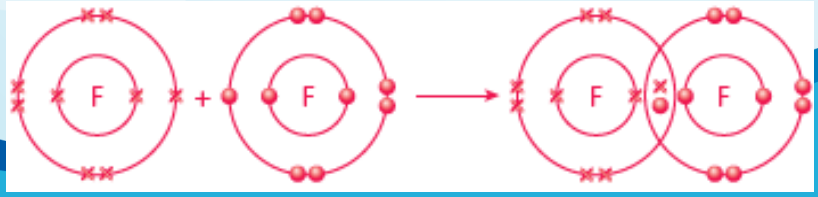
2,7

b) What is meant by the term 'diatomic'?

A diatomic molecule is a molecule made up of two atoms bond together.

c) With the aid of an electron diagram, describe how fluorine atoms make a molecule.

Two fluorine atoms share a pair of electrons in their outermost shells to make a fluorine molecule.



Covalent bonding in non-metals (p. 113)

Practice 8.1 (continued)

2 In terms of electrostatic forces of attraction, describe the nature of the following types of chemical bond.

a) Covalent bonds

A covalent bond is the electrostatic forces of attraction between the positively charged nuclei of the two bonded atoms and the negatively charged shared electrons.

b) Ionic bonds

An ionic bond is the strong electrostatic forces of attraction between oppositely charged ions.

8.3 Covalent bonding in compounds (p. 114)

- Atoms of different non-metals bond together to form **covalent compounds (共價化合物)**.

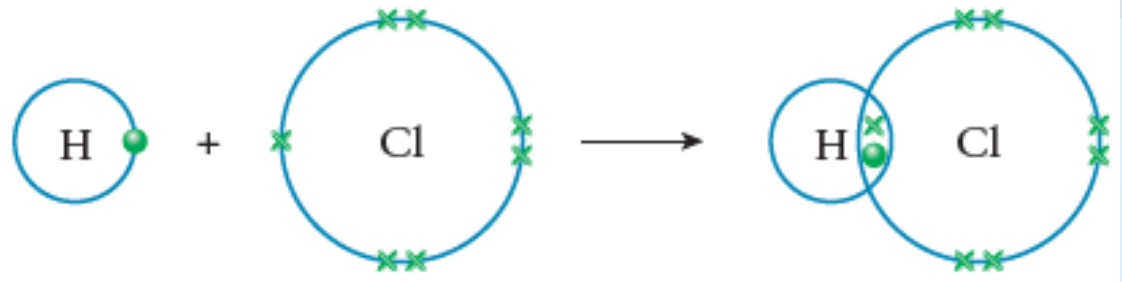
Hydrogen chloride

- Hydrogen chloride is a compound containing hydrogen and chlorine.
- A hydrogen atom has an electronic arrangement of 1 while a chlorine atom has an electronic arrangement of 2,8,7.

8.3 Covalent bonding in compounds (p. 114)

Hydrogen chloride

- A hydrogen atom shares a pair of electrons with a chlorine atom to make a hydrogen chloride molecule (HCl). Now, both atoms get the electronic arrangements of atoms of noble gases.



Formation of a covalent bond in a hydrogen chloride molecule (only electrons in the outermost shells are shown)

8.3 Covalent bonding in compounds (p. 114)

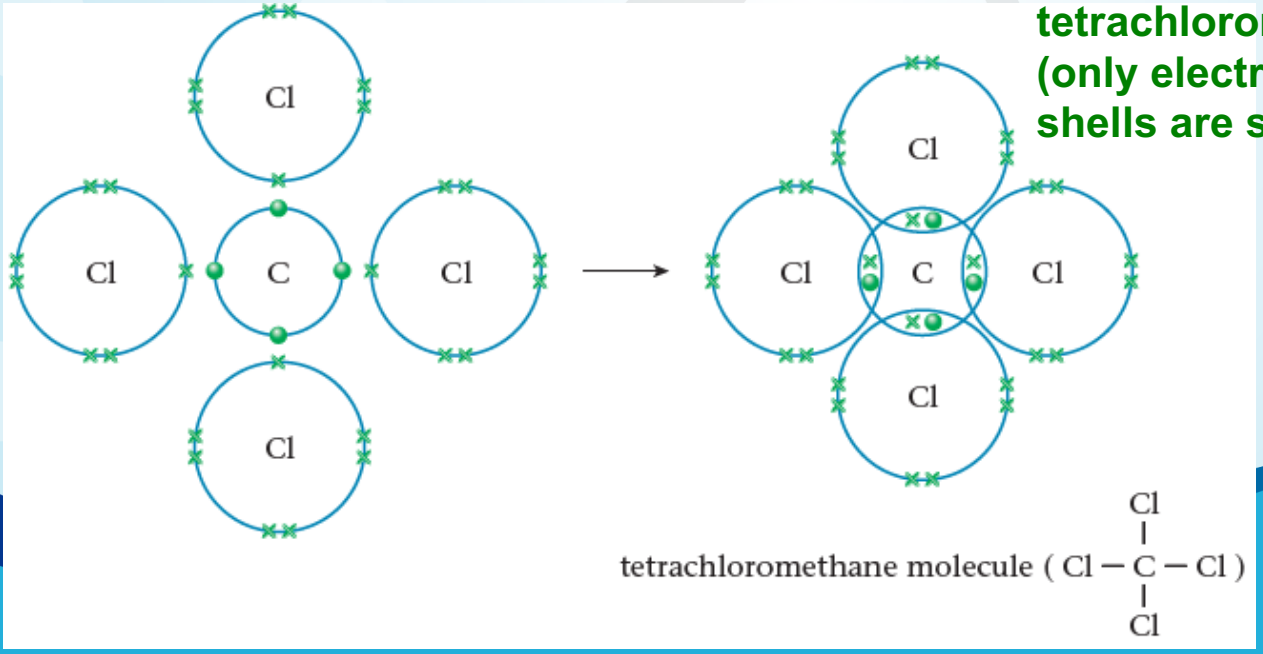
Tetrachloromethane

- **Tetrachloromethane (四氯甲烷)** is a compound containing carbon and chlorine.
- A carbon atom has an electronic arrangement of 2,4 while a chlorine atom has an electronic arrangement of 2,8,7.

8.3 Covalent bonding in compounds (p. 114)

Tetrachloromethane

- A carbon atom shares a pair of electrons with each of four chlorine atoms to make a tetrachloromethane molecule (CCl_4). Now, all the atoms get the electronic arrangements of atoms of noble gases.



Formation of covalent bonds in a tetrachloromethane molecule (only electrons in the outermost shells are shown)

8.3 Covalent bonding in compounds (p. 115)

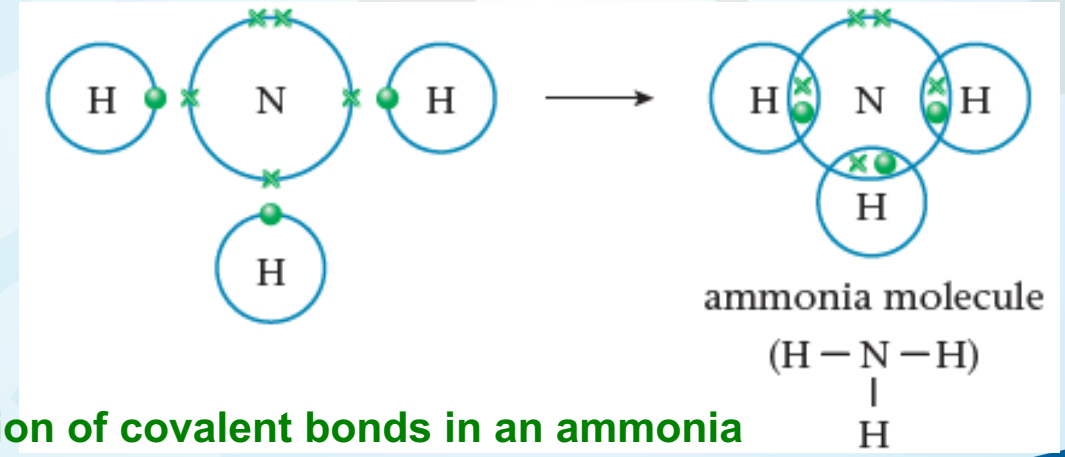
Ammonia

- **Ammonia (氨)** is a compound containing nitrogen and hydrogen.
- A nitrogen atom has an electronic arrangement of 2,5 while a hydrogen atom has an electronic arrangement of 1.

8.3 Covalent bonding in compounds (p. 115)

Ammonia

- A nitrogen atom shares a pair of electrons with each of three hydrogen atoms to make an ammonia molecule (NH_3). Now, all the atoms get the electronic arrangements of atoms of noble gases.

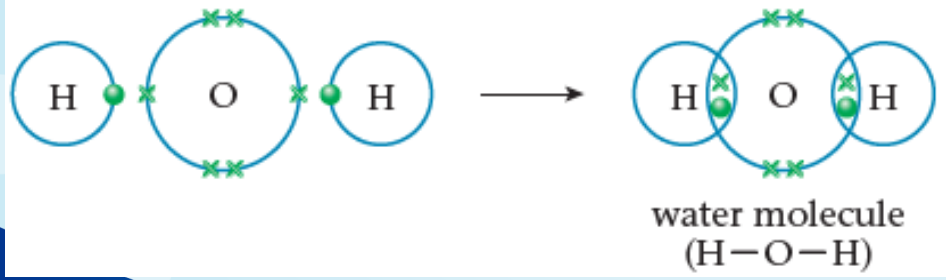


Formation of covalent bonds in an ammonia molecule (only electrons in the outermost shells are shown)

8.3 Covalent bonding in compounds (p. 116)

Water

- Water is a compound containing oxygen and hydrogen.
- An oxygen atom has an electronic arrangement of 2,6 while a hydrogen atom has an electronic arrangement of 1.
- An oxygen atom shares a pair of electrons with each of two hydrogen atoms to make a water molecule (H_2O). Now, all the atoms get the electronic arrangement of atoms of noble gases.



Formation of covalent bonds in a water molecule (only electrons in the outermost shells are shown)

8.3 Covalent bonding in compounds (p. 116)

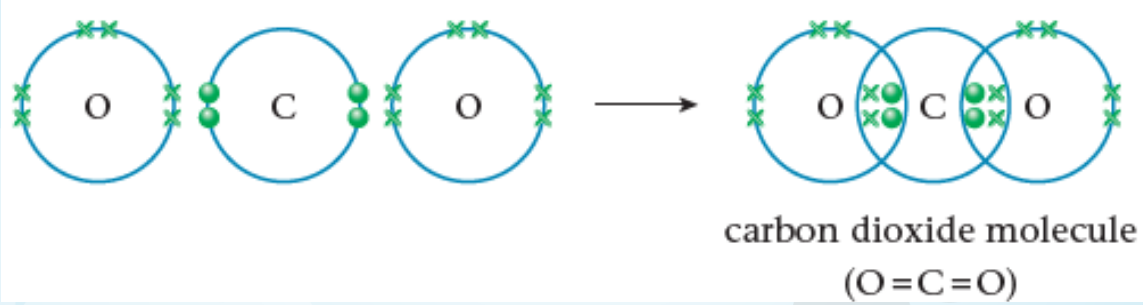
Carbon dioxide

- Multiple covalent bonds can exist in molecules of oxygen and nitrogen. They can exist in molecules of compounds too.
- Carbon dioxide is a compound containing carbon and oxygen.
- A carbon atom has an electronic arrangement of 2,4 while an oxygen atom has an electronic arrangement of 2,6.

8.3 Covalent bonding in compounds (p. 116)

Carbon dioxide

- A carbon atom shares two pairs of electrons with each of two oxygen atoms to make a carbon dioxide molecule (CO_2). Now, all the atoms get the electronic arrangements of atoms of noble gases.



Formation of covalent bonds in a carbon dioxide molecule (only electrons in the outermost shells are shown)

8.3 Covalent bonding in compounds (p. 117)

- From the group to which a non-metal belongs, you know how many electrons its atom needs so as to obtain the electronic arrangement of the atom of a noble gas.
- An oxygen atom (Group VI) needs another two electrons to obtain a stable electronic arrangement. Thus, it can form two single covalent bonds (e.g. in water, H_2O).

Group	Examples	Number of outermost shell electrons	Number of single covalent bond(s) its atom can form	Example of compound formed
IV	C and Si	4	4	CCl_4
V	N and P	5	3	NH_3
VI	O and S	6	2	H_2O
VII	F and Cl	7	1	HCl

8.3 Covalent bonding in compounds (p. 117)

Q (Example 8.1)

The atomic numbers of phosphorus and chlorine are 15 and 17 respectively.
They combine to form a compound with the molecular formula PCl_3.

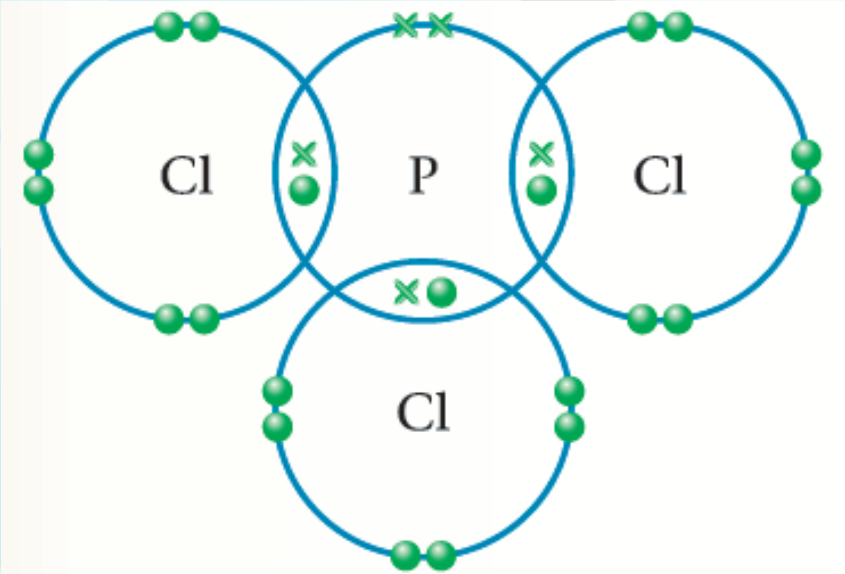
a) State the electronic arrangements of a phosphorus atom and a chlorine atom respectively.
b) Draw the electron diagram for the compound, showing electrons in the *outermost shells* only.
c) Give the molecular formula of the compound.

8.3 Covalent bonding in compounds (p. 117)

A

a) Electronic arrangement of a phosphorus atom is 2,8,5.
Electronic arrangement of a chlorine atom is 2,8,7.

b)

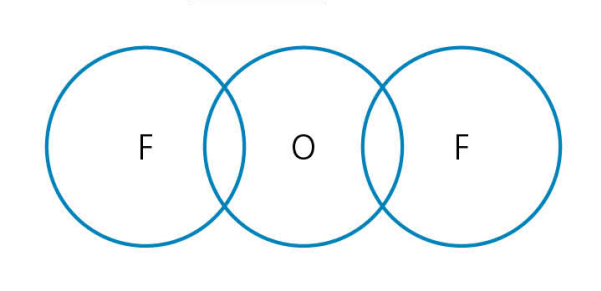


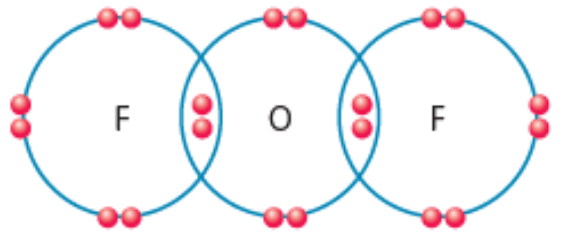
c) The molecular formula of the compound is PCl_3.

8.3 Covalent bonding in compounds (p. 118)

Practice 8.2

1 Oxygen and fluorine combine to form a covalent compound with the molecular formula OF_2.
Complete the electron diagram below for an OF_2 molecule.
Show electrons in the *outermost shells* only.



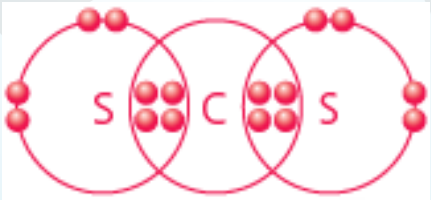


8.3 Covalent bonding in compounds (p. 118)

Practice 8.2 (continued)

2 The atomic numbers of carbon and sulphur are 6 and 16 respectively. The two non-metals combine to form a compound.

a) Draw the electron diagram of the compound, showing electrons in the *outermost shells* only.

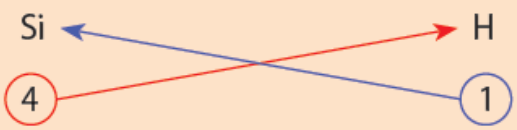
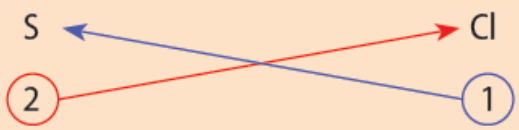


b) Give the molecular formula of the compound.

CS_2

8.4 Writing chemical formulae of covalent compounds (p. 118)

- Steps for working out the chemical formulae of covalent compounds.

Step	Compound formed from silicon and hydrogen	Compound formed from sulphur and chlorine
1 Write down the electronic arrangements of the atoms involved.	Si 2,8,4 ; H 1	S 2,8,6 ; Cl 2,8,7
2 Decide the number of electrons that each atom needs to obtain a stable electronic arrangement. Write down the number at the bottom of each atom.	Si 4 ; H 1	S 2 ; Cl 1
3 Decide the number of each type of atom in one molecule (cross multiply the numbers and the symbols).		
4 Combine the symbols and simplify the ratio if necessary.	SiH_4	SCl_2

8.4 Writing chemical formulae of covalent compounds (p. 119)

Practice 8.3

Give the chemical formula of the covalent compound formed when each pair of elements combine:

a) Hydrogen and bromine
HBr

b) Nitrogen and chlorine
NCl_3

c) Silicon and sulphur
SiS_2

8.5 Naming covalent compounds (p. 119)

- Follow the rules when naming covalent compounds that contain only two non-metals.

1 Give the name of the first non-metal in the chemical formula. Then add the name of the second non-metal, changing the ending of its name to '-ide'.

2 Use a prefix ('mono', 'di', 'tri' or 'tetra' for one, two, three or four) to tell the number of each type of atom in the chemical formula of the compound. The prefix 'mono' is only used for the second non-metal.

8.5 Naming covalent compounds (p. 119)

- Carbon and oxygen can form the compounds with chemical formulae CO and CO_2. When only one atom of the first element is present, the prefix 'mono' is usually omitted for the first element. Thus, the first compound is named carbon monoxide, and the second one is named carbon dioxide.
- When two atoms of the first element are present, the prefix 'di' is required for the first element. For example, the compound with chemical formula N_2O is named dinitrogen monoxide.

8.5 Naming covalent compounds (p. 120)

- Chemical formulae and names of some covalent compounds.

Chemical formula of compound	Name
SO_2	sulphur dioxide
SO_3	sulphur trioxide
NF_3	nitrogen trifluoride
N_2O_4	dinitrogen tetroxide

- Some compounds are called by common names. For example, H_2O is water and NH_3 is ammonia.

8.5 Naming covalent compounds (p. 120)

Practice 8.4

1 Name the following covalent compounds:

a) NF_3 Nitrogen trifluoride

b) Cl_2O Dichlorine monoxide

2 Write the chemical formulae of the following covalent compounds:

a) Dinitrogen trioxide N_2O_3

b) Sulphur hexafluoride SF_6

8.6 Molecular models (p. 120)

- The **ball-and-stick models (球棒模型)** are three-dimensional models where atoms of different elements are represented by balls of different colours and bonds are represented by sticks between the balls.
- The **space-filling models (填空模型)** are also three-dimensional models where atoms of different elements are represented by balls of different colours. They give a better idea of how close together different atoms are in molecules.

Building models of some covalent molecules

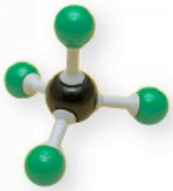
8.6 Molecular models (p. 121)

- Molecular models of molecules of non-metals.

Molecule of non-metal	Hydrogen (H—H)	Chlorine (Cl—Cl)	Oxygen (O=O)	Nitrogen (N≡N)
Ball-and-stick model				
Space-filling model				

8.6 Molecular models (p. 121)

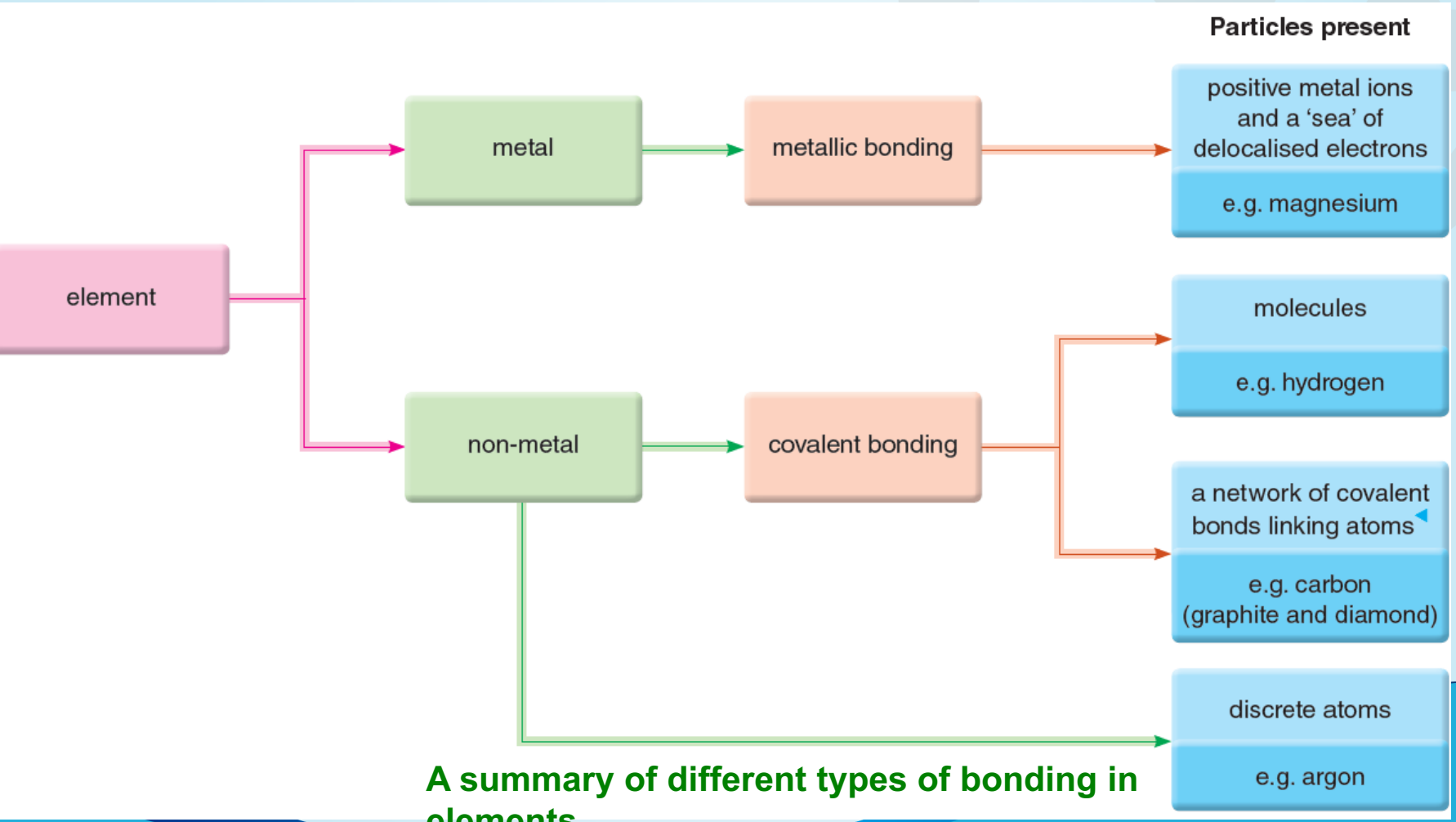
- Molecular models of molecules of compounds.

Molecule of compound	Hydrogen chloride (H—Cl)	Tetrachloromethane (Cl—C(Cl)—Cl, Cl)	Ammonia (H—N(H)—H)	Water (H—O—H)	Carbon dioxide (O=C=O)
Ball-and-stick model					
Space-filling model					

8.7 Predicting whether ionic or covalent compound is formed (p. 121)

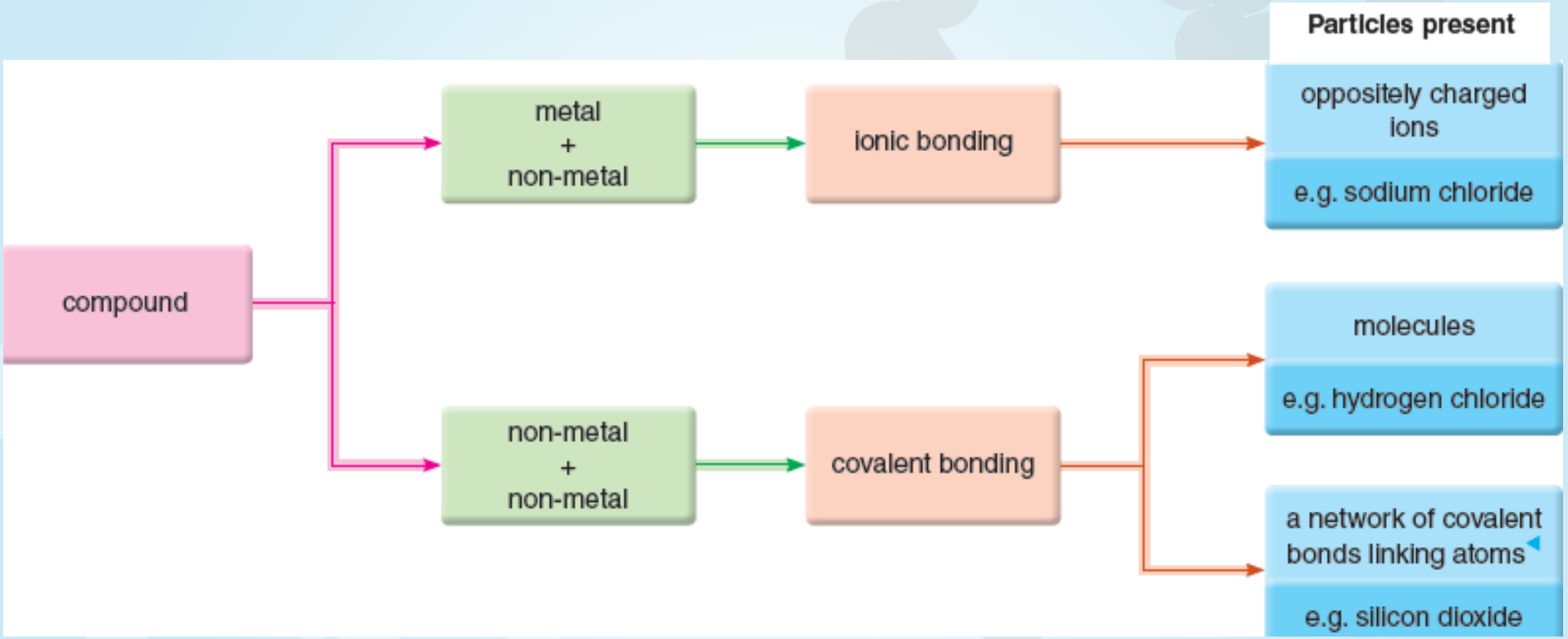
When a metal combines with a non-metal, an ionic compound forms. When different non-metals combine, a covalent compound forms.

8.7 Predicting whether ionic or covalent compound is formed (p. 122)



A summary of different types of bonding in elements

8.7 Predicting whether ionic or covalent compound is formed (p. 122)



A summary of different types of bonding in compounds

8.7 Predicting whether ionic or covalent compound is formed (p. 123)

Q (Example 8.2)

X, Y and Z are three elements in the Periodic Table. The sum of their atomic numbers is equal to 39. Moreover, both X and Y are Group VII elements, while the atomic number of X is smaller than that of Y.

a) What are elements X, Y and Z?

b) X and Y combine to form compound P.

i) Predict and explain whether compound P is ionic or covalent.

ii) Draw the electron diagram for compound P, showing electrons in the *outermost shells* only.

8.7 Predicting whether ionic or covalent compound is formed (p. 123)

Q (Example 8.2) (continued)

c) X and Z combine to form compound Q.

i) Predict and explain whether compound Q is ionic or covalent.

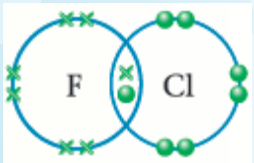
ii) Draw the electron diagram for compound Q, showing electrons in the *outermost shells* only.

8.7 Predicting whether ionic or covalent compound is formed (p. 123)

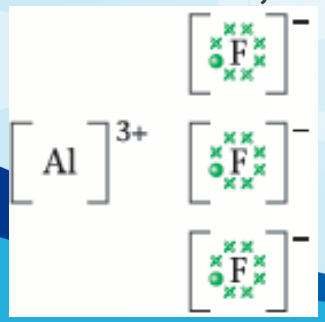
A

a) X: fluorine
Y: chlorine
Z: aluminium

b)i) When two non-metals (fluorine and chlorine) combine, a covalent compound forms.

ii) 

c)i) When a metal (aluminium) and a non-metal (fluorine) combine, an ionic compound forms.

ii) 

8.7 Predicting whether ionic or covalent compound is formed (p. 124)

Practice 8.5

1 Which of the following compounds have covalent bonding? Explain your answers.

Compound	Does it have covalent bonding? (yes / no)	Explanation
Hydrogen iodide		
Magnesium nitride		
Silver chloride		
Sulphur dioxide		

8.7 Predicting whether ionic or covalent compound is formed (p. 124)

Practice 8.5 (continued)

Compound	Does it have covalent bonding? (yes / no)	Explanation
Hydrogen iodide	yes	Both hydrogen and iodine are non-metals. A hydrogen atom shares electrons with an iodine atom to make a molecule.
Magnesium nitride	no	Magnesium is a metal while nitrogen is a non-metal. When magnesium and nitrogen combine, magnesium atoms lose electrons while nitrogen atoms gain electrons.
Silver chloride	no	Silver is a metal while chlorine is a non-metal. When silver and chlorine combine, silver atoms lose electrons while chlorine atoms gain electrons.
Sulphur dioxide	yes	Both sulphur and oxygen are non-metals. A sulphur atom shares electrons with two oxygen atoms to make a molecule.

8.7 Predicting whether ionic or covalent compound is formed (p. 124)

Practice 8.5 (continued)

2 Atoms of elements X, Y and Z have 1, 16 and 19 electrons respectively.

Elements X and Y combine to form compound P while elements Y and Z combine to form compound Q.

For each compound,

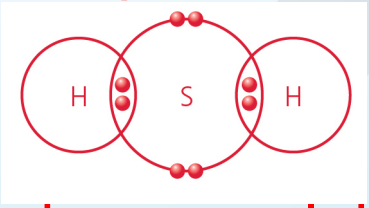
a) predict whether it is ionic or covalent;

Compound P: covalent

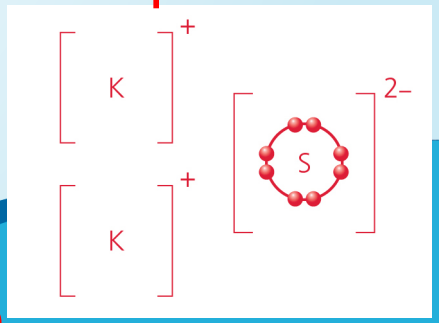
Compound Q: Ionic

b) draw the electron diagram, showing electrons in the *outermost shells* only;

Compound P:



Compound Q:



c) give its name.

Compound P: hydrogen sulphide

Compound Q: Potassium sulphide

8.8 Dative covalent bonds (p. 124)

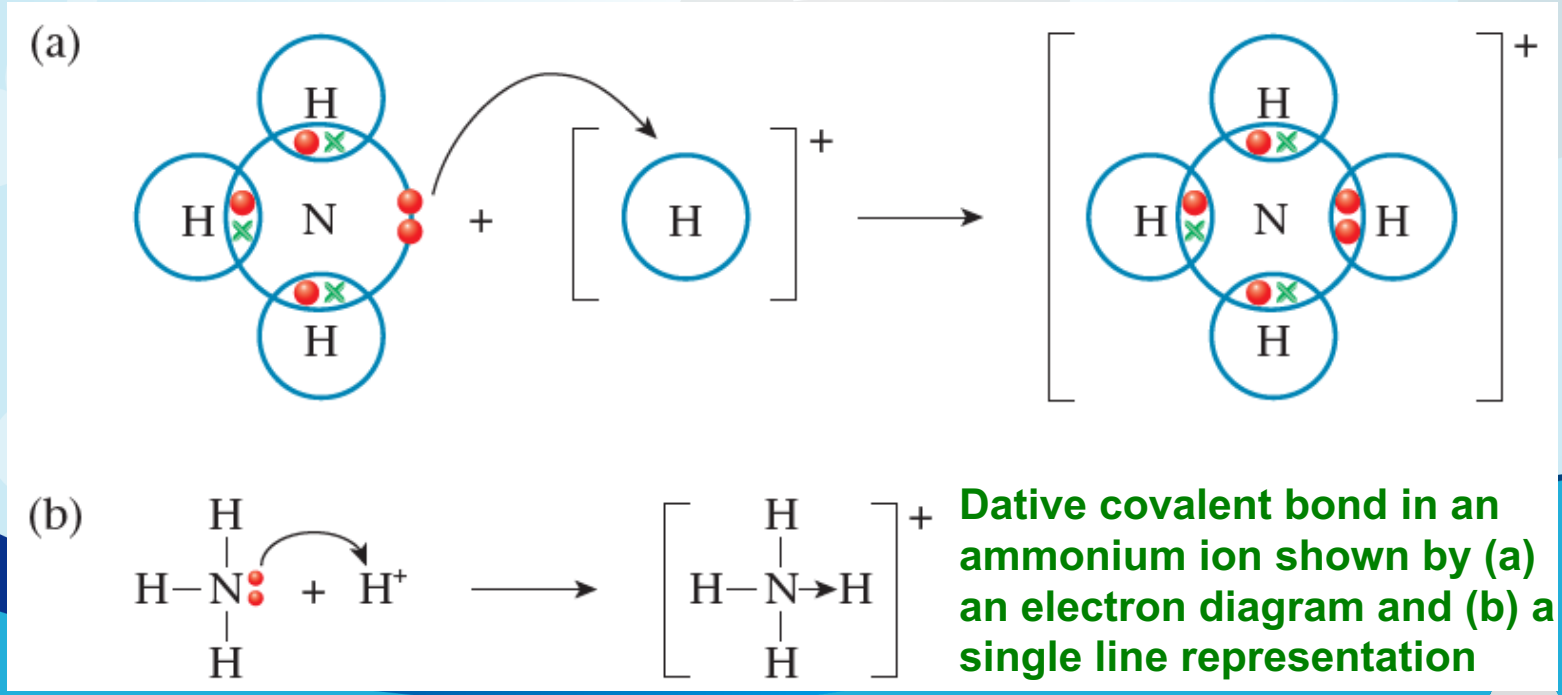
- In a covalent bond, two atoms share a pair of electrons and each atom supplies one electron to make up the pair. If one atom provides both the electrons to share with another atom. This is called a **dative covalent bond (配位共價鍵)**.
- Occurrence of dative covalent bonding needs
  - one atom having a lone pair of electrons;
  - a second particle having a vacant site in its outermost shell to accept the lone pair (i.e. an **electron-deficient (缺電子的)** chemical species).

A dative covalent bond is a type of covalent bond in which both electrons come from the same atom.

8.8 Dative covalent bonds (p. 125)

Ammonium ion (NH_4^+)

- An **ammonium ion (銨離子)** is formed when an ammonia molecule combines with a hydrogen ion (H^+). The hydrogen ion has a vacant site in its electron shell. The nitrogen atom of the ammonia molecule has a lone pair of electrons.

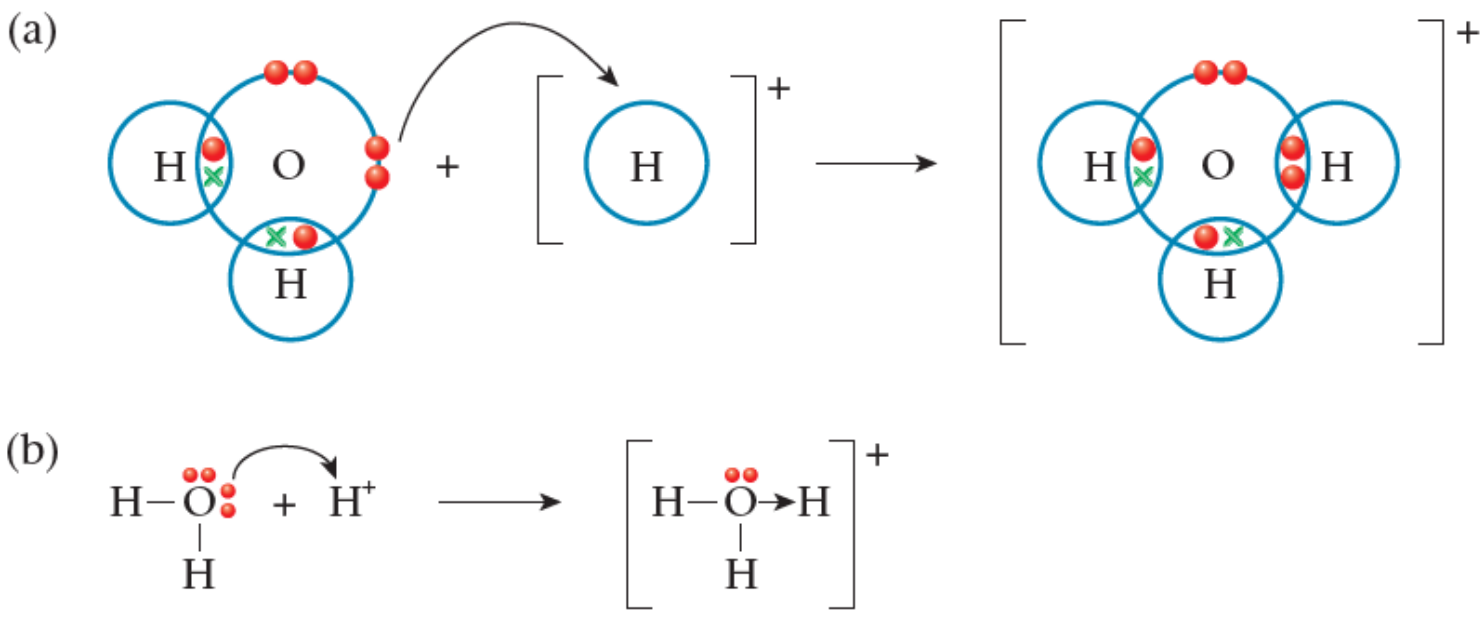


Dative covalent bond in an ammonium ion shown by (a) an electron diagram and (b) a single line representation

8.8 Dative covalent bonds (p. 125)

Hydroxonium ion or hydronium ion (H_3O^+)

- A **hydroxonium ion / hydronium ion (水合氫離子)** is formed when a water molecule combines with a hydrogen ion (H^+).

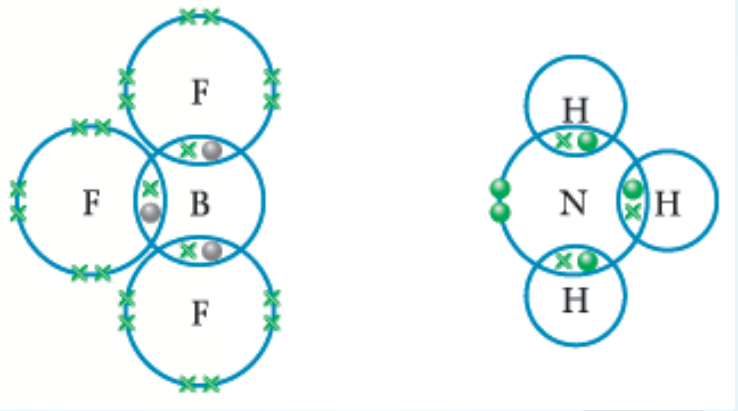


Dative covalent bond in a hydroxonium ion or a hydronium ion shown by (a) an electron diagram and (b) a single line representation

8.8 Dative covalent bonds (p. 126)

Q (Example 8.3)

Both boron trifluoride (BF_3) and ammonia (NH_3) exist as simple molecules.



BF_3 reacts with NH_3 to give F_3BNH_3. Describe the bond formation between BF_3 and NH_3.

8.8 Dative covalent bonds (p. 126)

A

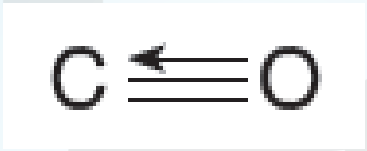
In BF_3, there are only three pairs of electrons in the outermost shell of the boron atom. The electronic arrangement of an atom of noble gas has not been obtained. Thus, a vacant site exists in its outermost shell.

By sharing the lone pair of electrons from the nitrogen atom of ammonia, the boron atom gets the electronic arrangement of a neon atom.

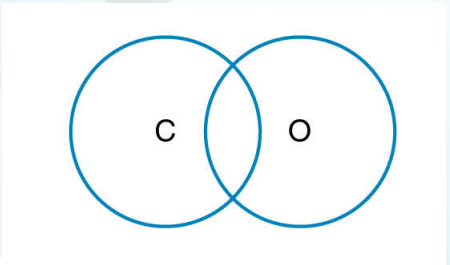
8.8 Dative covalent bonds (p. 126)

Practice 8.6

Carbon forms carbon monoxide (CO). The bonding in CO can be represented as below:



Complete the electron diagram below for a CO molecule. Show electrons in the *outermost shells* only.



8.9 Relative molecular mass and formula mass (p. 127)

Relative molecular mass

- The **relative molecular mass (相對分子質量)** is used to describe the relative masses of molecules.

For an element or a compound existing as discrete molecules, the relative molecular mass is the sum of the relative atomic masses of all the atoms which make up one molecule.

8.9 Relative molecular mass and formula mass (p. 127)

- Examples of calculating relative molecular masses.

Element / compound	Molecular formula	Atoms in one molecule	Relative atomic mass(es)	Relative molecular mass
Nitrogen	N_2	2 N	N = 14.0	2 x 14.0 = 28.0
Tetrachloromethane	CCl_4	1 C 4 Cl	C = 12.0 Cl = 35.5	1 x 12.0 + 4 x 35.5 = 154.0

8.9 Relative molecular mass and formula mass (p. 127)

Formula mass

- **Formula mass (式量)** is used to describe the relative masses of ionic compounds.

Formula mass of an ionic compound is the sum of the relative atomic masses of all the atoms in one formula unit of the compound.

8.9 Relative molecular mass and formula mass (p. 128)

- Examples of calculating formula masses.

Ionic compound	Formula unit	Atoms in one formula unit	Relative atomic masses	Formula mass
Magnesium nitrate	$Mg(NO_3)_2$	1 Mg 2 N 6 O	Mg = 24.3 N = 14.0 O = 16.0	1 x 24.3 + 2 x 14.0 + 6 x 16.0 = 148.3
Ammonium sulphate	$(NH_4)_2SO_4$	2 N 8 H 1 S 4 O	N = 14.0 H = 1.0 S = 32.1 O = 16.0	2 x 14.0 + 8 x 1.0 + 1 x 32.1 + 4 x 16.0 = 132.1

8.9 Relative molecular mass and formula mass (p. 128)

Practice 8.7

1 Work out the relative molecular masses of the elements and compounds below.

a) Ammonia (NH_3) $14.0 + 3 \times 1.0 = 17.0$
b) Chlorine (Cl_2) $2 \times 35.5 = 71.0$
c) Oxygen (O_2) $2 \times 16.0 = 32.0$
d) Water (H_2O) $2 \times 1.0 + 16.0 = 18.0$

(Relative atomic masses: H = 1.0, N = 14.0, O = 16.0, Cl = 35.5)

8.9 Relative molecular mass and formula mass (p. 128)

Practice 8.7

2 Work out the formula masses of the ionic compounds below.

a) Ammonium carbonate ($(NH)_2CO_3$)

2 x 14.0 + 8 x 1.0 + 12.0 + 3 x 16.0 = 96.0

b) Calcium phosphate ($Ca_3(PO_4)_2$)

3 x 40.1 + 2 x 31.0 + 8 x 16.0 = 310.3

c) Potassium sulphide (K_2S)

2 x 39.1 + 32.1 = 110.3

(Relative atomic masses: H = 1.0, C = 12.0, N = 14.0, O = 16.0, P = 31.0, S = 32.1, K = 39.1, Ca = 40.1)

Key terms (p. 129)

covalent bond	共價鍵	tetrachloromethane	四氯甲烷
molecule	分子	ammonia	氨
bond pair of electrons	鍵合電子對	ball-and-stick model	球棒模型
diatomic molecule	雙原子分子	space-filling model	填空模型
monatomic molecule	單原子分子	dative covalent bond	配位共價鍵
molecular formula	分子式	electron-deficient	缺電子的
lone pair of electrons	孤電子對	ammonium ion	銨離子
double bond	雙鍵	hydroxonium ion / hydronium ion	水合氫離子
triple bond	三鍵	relative molecular mass	相對分子質量
covalent compound	共價化合物	formula mass	式量

Summary (p. 130)

1 A molecule forms when two or more atoms are joined by covalent bonds.

2 A covalent bond forms when two atoms share a pair of electrons.

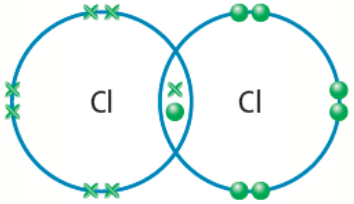
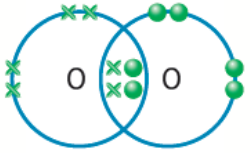
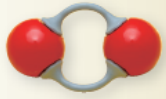
3 A covalent bond is the electrostatic forces of attraction between the positively charged nuclei of the two bonded atoms and the negatively charged shared electrons.

4 A lone pair of electrons is a pair of electrons in the outermost shell of one of the atoms in a molecule which is not involved in bonding.

5 Atoms of different non-metals bond together to form covalent compounds.

Summary (p. 130)

6 The table below shows the electron diagrams and models of molecules of some common non-metals and covalent compounds.

Molecule	Electron diagram (only electrons in the outermost shells are shown)	Ball-and-stick model
Hydrogen		
Chlorine		
Oxygen		

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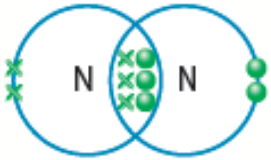
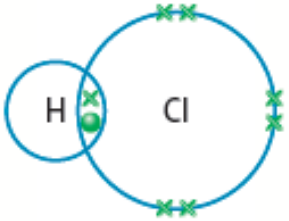
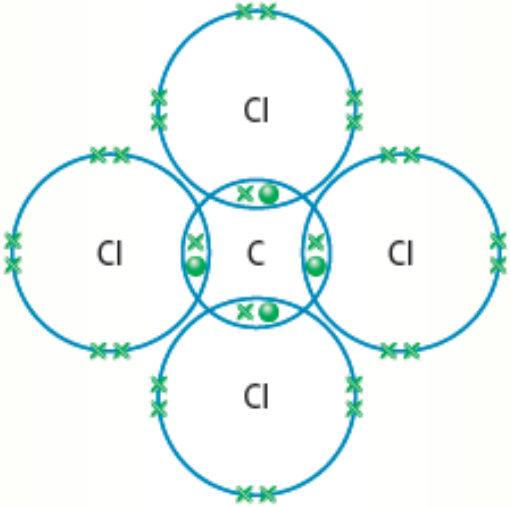
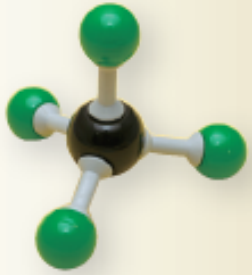
Summary (p. 130)

Molecule	Electron diagram (only electrons in the outermost shells are shown)	Ball-and-stick model
Nitrogen		
Hydrogen chloride		
Tetrachloromethane		

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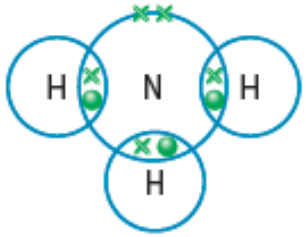
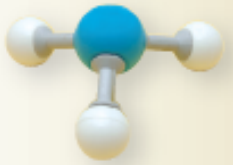
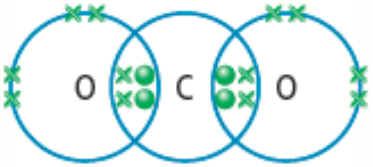
Summary (p. 131)

Molecule	Electron diagram (only electrons in the outermost shells are shown)	Ball-and-stick model
Ammonia		
Water		
Carbon dioxide		

Summary (p. 131)

7 When naming a covalent compound containing only two non-metals:

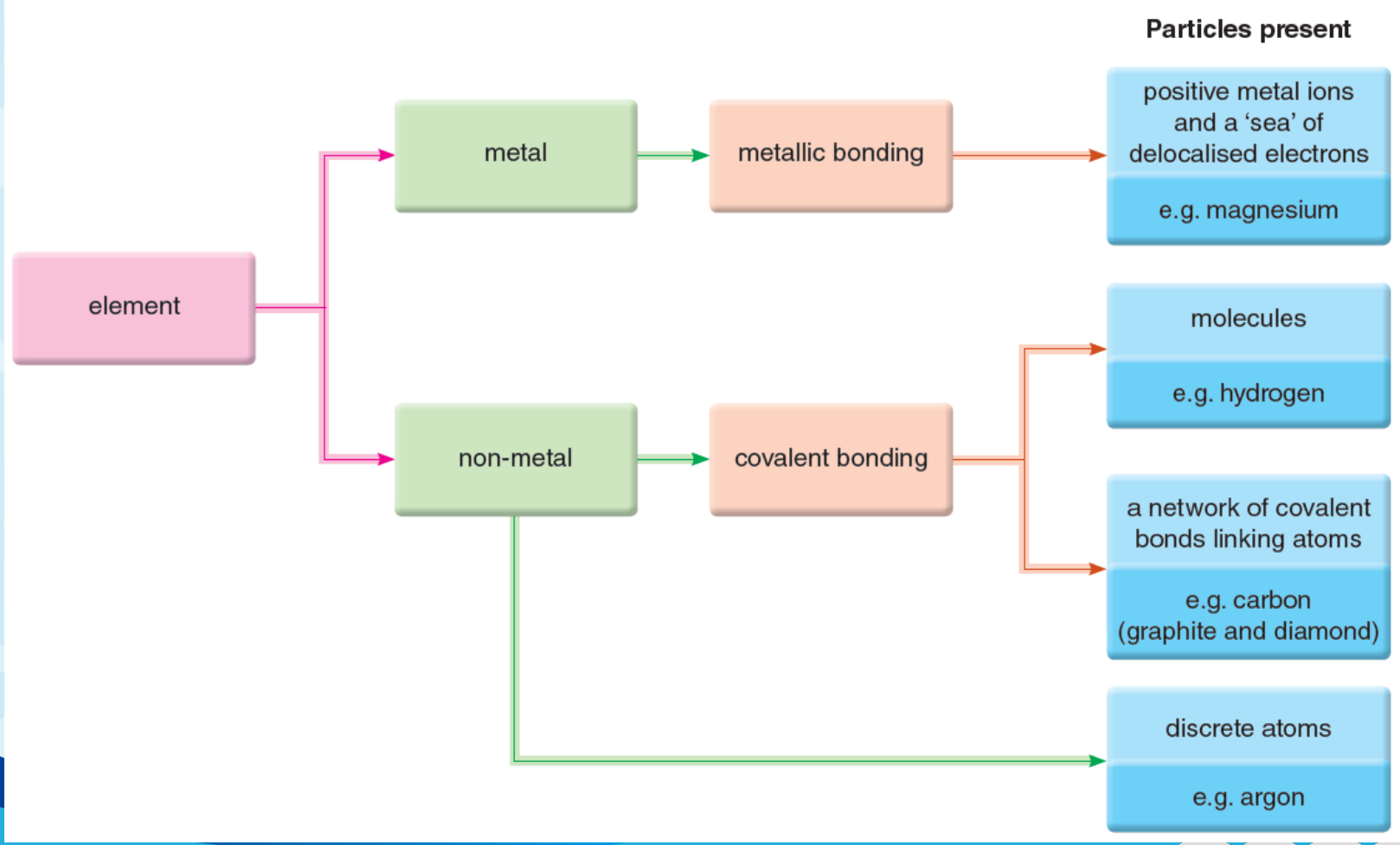
- give the name of the first non-metal in the chemical formula, then add the name of the second non-metal (with the end of the name changed to 'ide');
- use a prefix ('mono', 'di', 'tri' or 'tetra', etc.) to tell the number of each type of atom in the chemical formula of the compound.

8 a) When a metal combines with a non-metal, an ionic compound forms.

b) When different non-metals combine, a covalent compound forms.

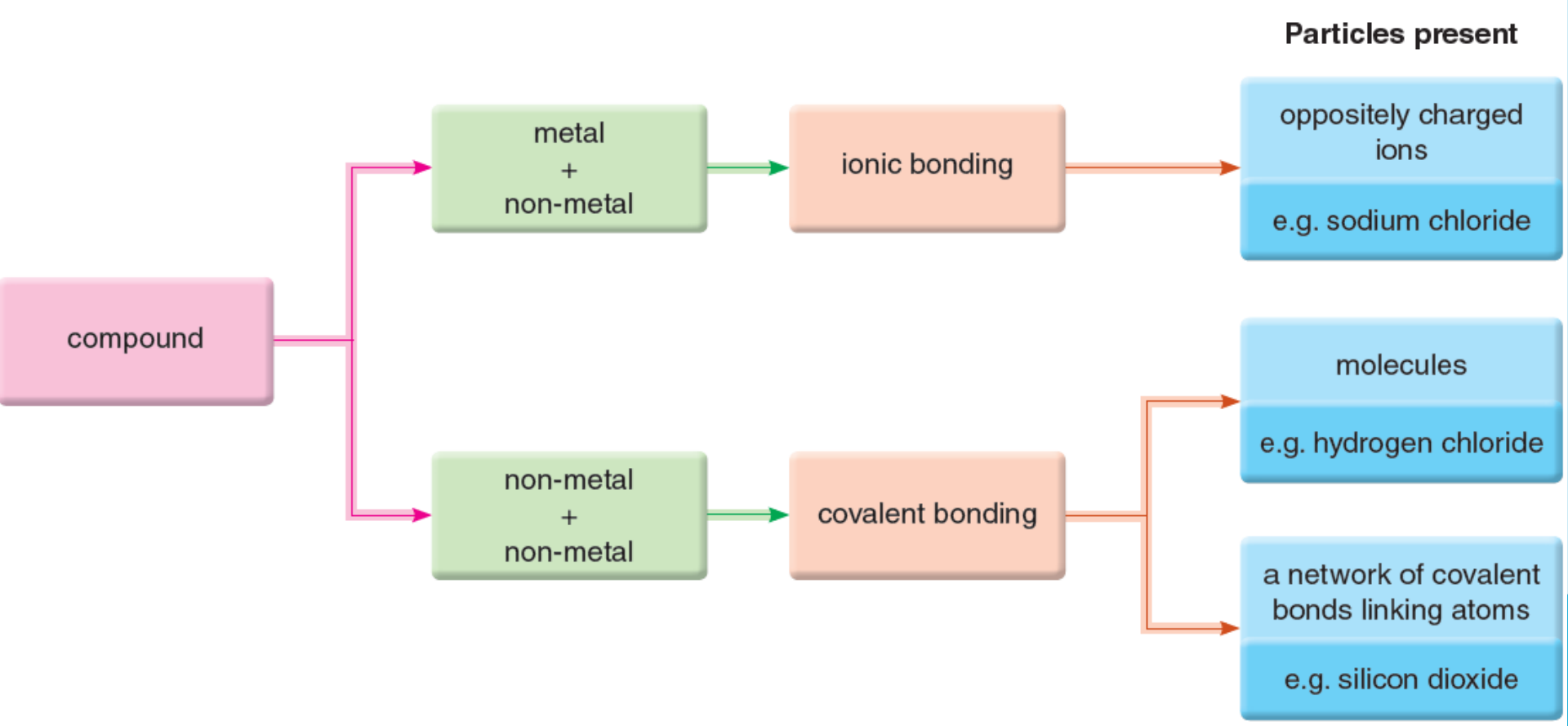
Summary (p. 132)

9 a) The following diagram shows a summary of different types of bonding in elements.



Summary (p. 132)

b) The following diagram shows a summary of different types of bonding in compounds.



Summary (p. 133)

10 A dative covalent bond is a type of covalent bond in which both electrons come from the same atom. The following diagram shows the formation of a dative covalent bond in an ammonium ion.

11 For an element or a compound existing as discrete molecules, the relative molecular mass is the sum of the relative atomic masses of all the atoms which make up one molecule.

12 Formula mass of an ionic compound is the sum of the relative atomic masses of all atoms in one formula unit of the compound.

Unit Exercise (p. 134)

Note: Questions are rated according to ascending level of difficulty (from 1 to 5):

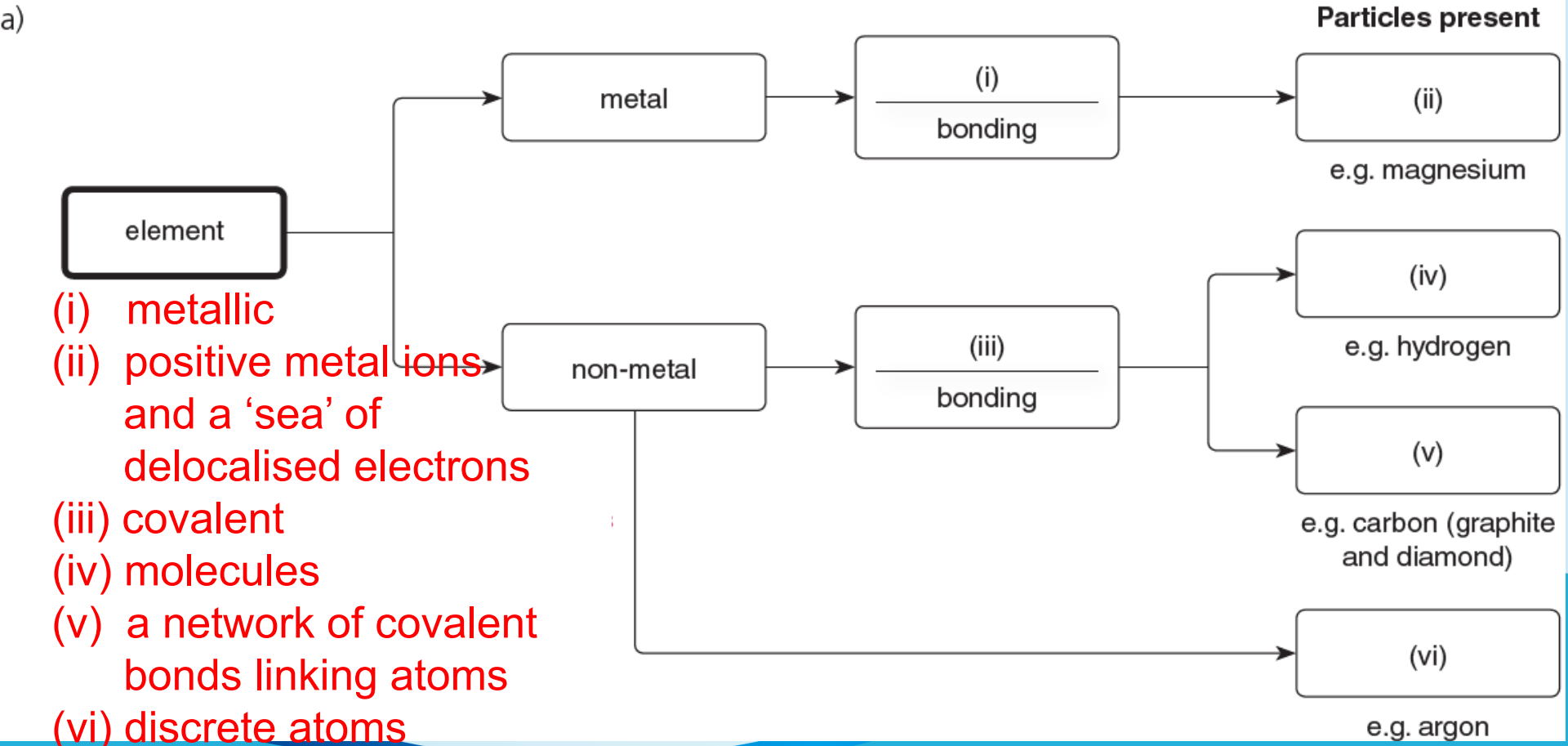
 question targeted at level 3 and above;
 question targeted at level 4 and above;
 question targeted at level 5.
' * ' indicates 1 mark is given for effective communication.

Unit Exercise (p. 134)

Part I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

a)



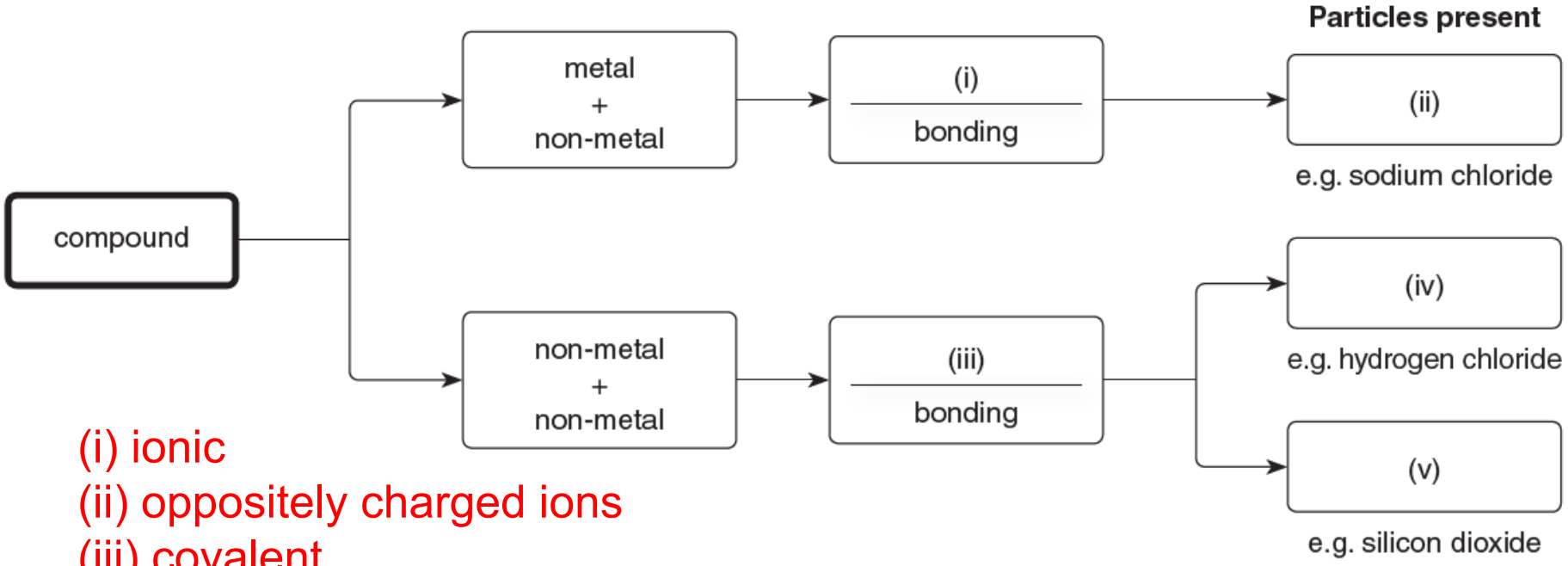
(i) metallic
(ii) positive metal ions and a 'sea' of delocalised electrons
(iii) covalent
(iv) molecules
(v) a network of covalent bonds linking atoms
(vi) discrete atoms

Unit Exercise (p. 134)

Part I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

b)



(i) ionic
(ii) oppositely charged ions
(iii) covalent
(iv) molecules
(v) a network of covalent bonds linking atoms

Unit Exercise (p. 134)

Part II MUTIPLE CHOICE QUESTIONS

2 A molecule is

A a group of atoms bonded by ionic bonds.
B a group of atoms bonded by covalent bonds.
C a group of ions bonded by covalent bonds.
D a group of atoms bonded by metallic bonds.

(Edexcel Advanced Subsidiary GCE, Unit 1, Jan. 2012, 1)

Answer：B

Unit Exercise (p. 134)

3 The electron diagrams of atoms X and Y are shown.

X and Y form a covalent compound.

What is the molecular formula of the compound?

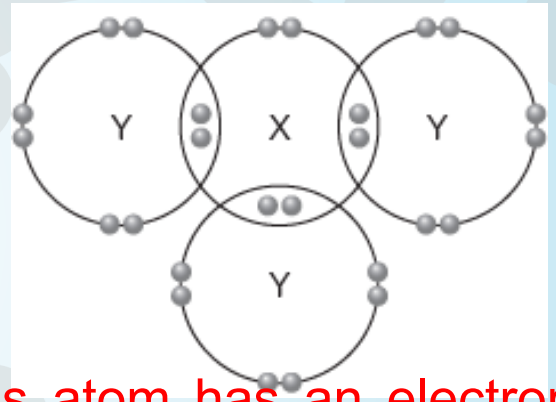
A XY
B XY_4
C YX_2
D YX_4

Explanation:
An atom of Y shares a pair of electrons with each of four atoms of X to make a molecule of molecular formula YX_4.

Answer : D

Unit Exercise (p. 134)

4 The electron diagram of a compound formed between elements X and Y is shown below.
(Only electrons in the *outermost shells* are shown.)



Which of the following combinations about X and Y is correct?

	X	Y
A	carbon	chlorine
B	silicon	oxygen
C	nitrogen	oxygen
D	phosphorus	chlorine

Answer : D

Explanation:
A phosphorus atom has an electronic arrangement of 2,8,5 while a chlorine atom has an electronic arrangement of 2,8,7.
A phosphorus atom shares a pair of electrons with each of three chlorine atoms so that all the atoms get the electronic arrangements of atoms of noble gases.

Unit Exercise (p. 134)

5 Elements X and Y form a covalent compound with chemical formula XY_2.

Which of the following combinations about X and Y is correct?

	X	Y
A	carbon	sulphur
B	hydrogen	fluorine
C	lithium	sulphur
D	magnesium	fluorine

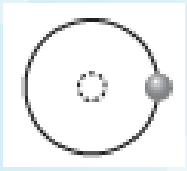
Answer : A

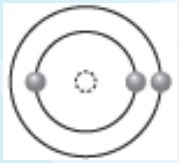
Explanation:
Carbon and sulphur are both non-metals. They combine to form a covalent compound.
A carbon atom has an electronic arrangement of 2,4 while a sulphur atom has an electronic arrangement of 2,8,6.
A carbon atom shares two pairs of electrons with each of two sulphur atoms to make a CS_2 molecule.

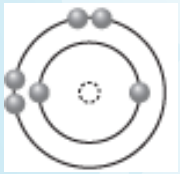
Unit Exercise (p. 134)

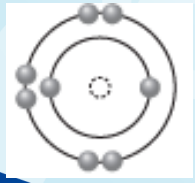
6 The diagrams show the electronic arrangements in the atoms of four elements.

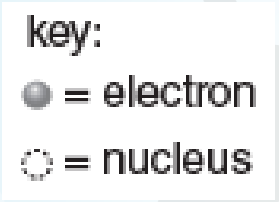
Which of the elements does NOT form a covalent bond?

A 

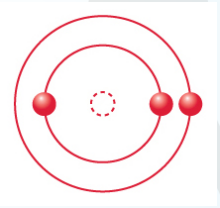
B 

C 

D 



Explanation:



is lithium atom. Lithium is a metal. It does NOT form a covalent bond.

Answer : B

Unit Exercise (p. 134)

7 Electrons from atoms of elements are shared in a compound containing two elements.

Which of the following compounds matches this description?

A Ammonia
B Copper(II) chloride
C Potassium sulphide
D Zinc oxide

Explanation:
Ammonia contains hydrogen and nitrogen. Both hydrogen and nitrogen are non-metals. Their atoms share electrons to form a covalent compound.

Answer : A

Unit Exercise (p. 134)

8 If X represents the element of atomic number 9 and Y represents the element of atomic number 20, the compound formed between these two elements is

A covalent, YX_2.
B ionic, YX_2.
C covalent, YX.
D ionic, YX.

Explanation:
X is fluorine (a non-metal) while Y is calcium (a metal). They combine to form an ionic compound.
When calcium atoms combine with fluorine atoms, two electrons from each calcium atom are transferred to two fluorine atoms, one for each. The chemical formula of the compound formed is CaF2, i.e. YX_2.

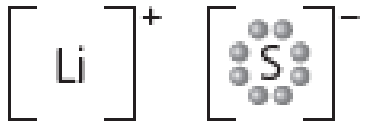
Answer : B

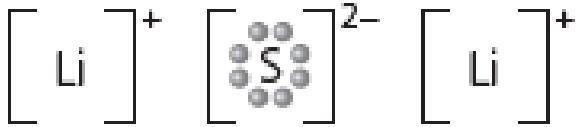
(Edexcel Advanced Subsidiary GCE, Unit 1, Jun. 2012, 17)

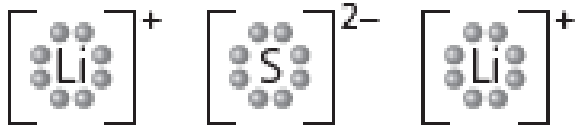
Unit Exercise (p. 134)

9 Which of the following is the electron diagram (only electrons in the *outermost shells* are shown) of lithium sulphide?

A 

B 

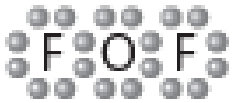
C 

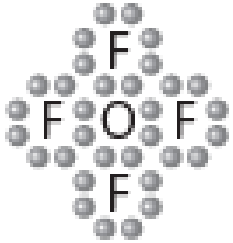
D 

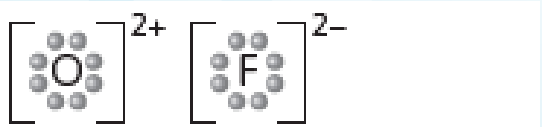
Answer：C

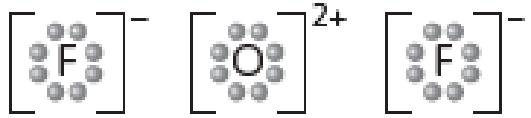
Unit Exercise (p. 134)

10 Which of the following is the electron diagram (only electrons in the *outermost shells* are shown) of a compound formed between oxygen and fluorine?

A 

B 

C 

D 

Explanation:
Both oxygen and fluorine are non-metals. Their atoms share electrons to form a covalent compound.

Answer : A

Unit Exercise (p. 134)

11 Which of the following compounds contains both ionic and covalent bonding?

A $NaCl$
B NH_4Cl
C CCl_4
D PCl_3

Explanation:
NH_4^+ ion is formed when NH_3 molecule combines with H^+ ion via dative covalent bonding.
Ionic bonding exists between NH_4^+ ion and Cl^- ion.

Answer : A

Unit Exercise (p. 134)

12 X is a Period 3 element. It forms a compound with aluminium of chemical formula Al_2X_3. X forms a compound with carbon. Which of the following is most likely to be the chemical formula of the compound?

A CX_2
B CX_3
C C_2X
D C_2X_3

Explanation:
The chemical formula of the compound is Al_2X_3. One aluminium ion carries three positive charges. The compound has no overall charges. In the compound, two Al^{3+} ions are needed for three ions of X to make the total charge zero. Thus, the ion of X should carry two negative charges. X is sulphur. A carbon atom has an electronic arrangement of 2,4 while a sulphur atom has an electronic arrangement of 2,8,6.
A carbon atom shares two pairs of electrons with each of two sulphur atoms to make a CS_2 molecule.

Answer : A

Unit Exercise (p. 134)

13 Which of the following molecules contain(s) only single covalent bond(s)?

(1) Br_2
(2) CO_2
(3) CH_4

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer : C

Unit Exercise (p. 134)

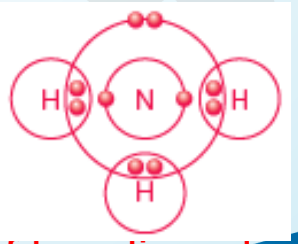
14 Which of the following statements about an ammonia molecule is / are correct?

(1) The number of bonding electrons contributed by each hydrogen atom in the molecule is 1.
(2) The number of bonding electrons contributed by the nitrogen atom in the molecule is 5.
(3) The total number of electrons in the molecule is 8.

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer : A

Explanation:
The electron diagram of an ammonia molecule is shown below.



(2) The number of bonding electrons contributed by the nitrogen atom in the molecule is 3.
(3) The total number of electrons in the molecule is 10.

Unit Exercise (p. 134)

15 In which of the compounds is / are electrons shared between atoms?

(1) Hydrogen chloride
(2) Sodium chloride
(3) Silver chloride

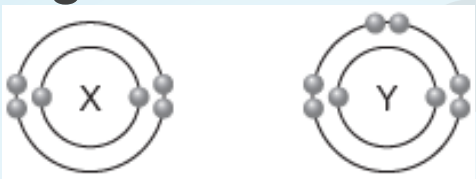
A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Explanation:
(1) Hydrogen chloride is a covalent compound.

Answer : A

Unit Exercise (p. 134)

16 The electron diagrams of atoms of elements X and Y are shown.



Elements X and Y combine to form a compound. Which of the following statements about the compound are correct?

(1) It is a covalent compound.
(2) Its chemical formula is X_2Y.
(3) It is a gas at room temperature and pressure.

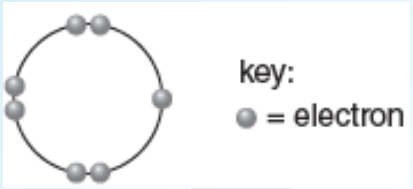
A (1) and (2) only
B (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

Explanation:
X is carbon while Y is oxygen.
A carbon atom shares two pairs of electrons with each of two oxygen atoms to make a CO_2 molecule.

Answer : B

Unit Exercise (p. 134)

17 Element X has seven electrons in the outermost shell of its atom.



How could element X react?

(1) By gaining one electron to form a negative ion.
(2) By losing seven electrons to form a positive ion.
(3) By sharing a pair of electrons with an atom of another element to form a covalent bond.

A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Explanation:
(1) An atom of X gains one electron so as to obtain a stable outermost shell of 8 electrons.

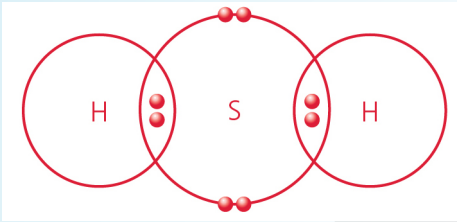
Answer : C

Unit Exercise (p. 134)

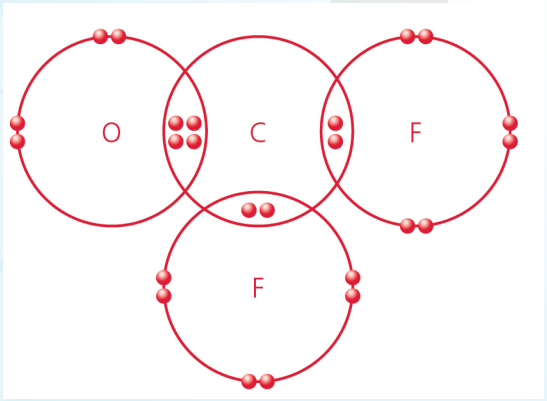
Part III STRUCTURED QUESTIONS

18 Draw electron diagrams for the following compounds, showing electrons in the *outermost shells* only.

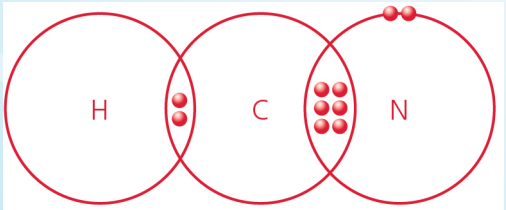
a) H_2S



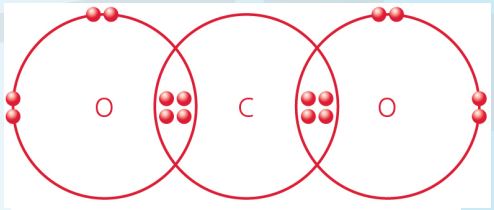
b) COF_2



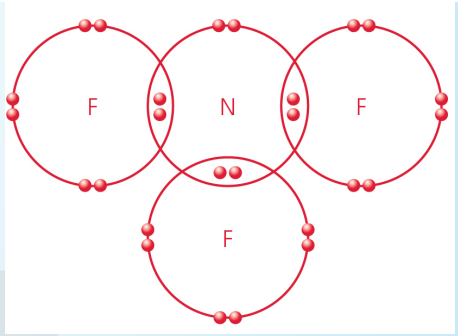
c) HCN



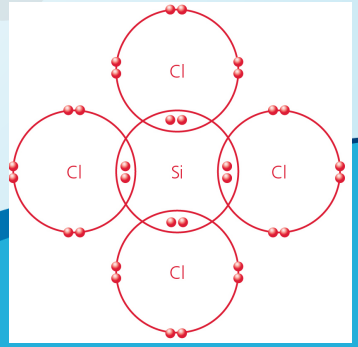
d) CO_2



e) NF_3



f) $SiCl_4$



Unit Exercise (p. 134)

19 a) Explain how the atoms are held together by the covalent bond in a molecule of hydrogen.

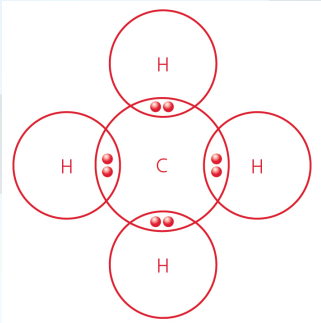
The two hydrogen atoms in a hydrogen molecule are held together by the strong electrostatic forces of attraction between their positively charged nuclei and the negatively charged shared electrons. (1)

Unit Exercise (p. 134)

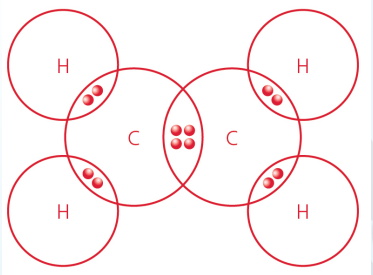
19 (continued)

b) Draw the electron diagrams for

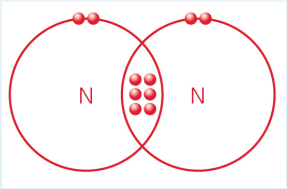
i) methane, CH_4;



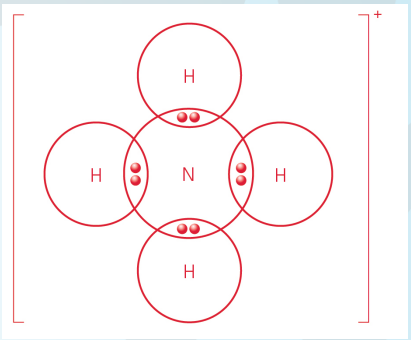
ii) ethene, $CH_2=CH_2$;



iii) nitrogen, N_2;



iv) ammonium ion, NH_4^+.



(Edexcel Advanced Subsidiary GCE, Unit 1, Jun. 2012, 26(a)–(b))

Unit Exercise (p. 134)

20 Name the following covalent compounds:

a) NO_2 Nitrogen dioxide (1)

b) SiF_4 Silicon tetrafluoride (1)

c) P_2S_3 Diphosphorus trisulphide (1)

Unit Exercise (p. 134)

21 The elements of Group 0 are called noble gases. They all exist as monatomic molecules.

a) Name THREE of the noble gases.

Any three of the following:
- Helium (1)
- Neon (1)
- Argon (1)
- Krypton (1)
- Xenon (1)
- Radon (1)

b) i) What is meant by 'monatomic molecule'?

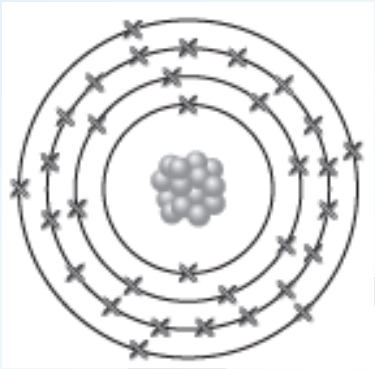
Discrete atom (1)

ii) Explain why the noble gases, unlike all other gaseous elements that exist as diatomic molecules, are monatomic.

Each atom of noble gases has a full outermost electron shell. An outermost shell of 8 electrons (or 2 electrons for helium) is extremely stable. (1) Thus, each of these atoms has little tendency to combine with other atoms.

Unit Exercise (p. 134)

22 The diagram below shows the structure of an atom of arsenic (As).



a) To which group and period of the Periodic Table does arsenic belong? Group V (1)
Period 4 (1)

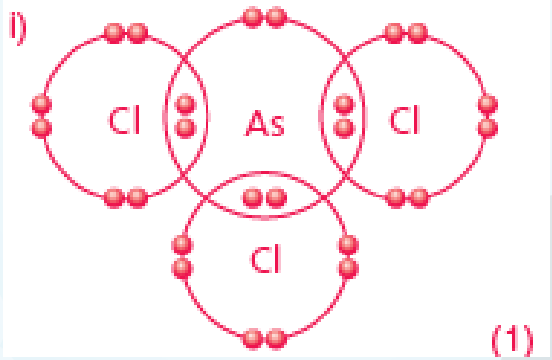
b) How many protons does the nucleus of this atom contain? 33 (1)

Unit Exercise (p. 134)

22 (continued)

c) Arsenic trichloride ($AsCl_3$) exists as simple covalent molecules.

i) Draw the electron diagram for arsenic trichloride, showing electrons in the *outermost shells* only.



ii) What is the relative molecular mass of arsenic trichloride? 74.9 + 3 x 35.5 = 181.4 (1)

(Relative atomic masses: Cl = 35.5, As = 74.9)

Unit Exercise (p. 134)

23 What type of bonding is formed when each of the following pairs of elements combine to form a compound? Give the chemical formula and the name of each compound formed.

Elements combined	Ionic / covalent compound	Chemical formula of compound	Name of compound	
Carbon and sulphur	covalent	CS_2	carbon disulphide	(3)
Lithium and bromine	ionic	LiBr	lithium bromide	(3)
Magnesium and nitrogen	ionic	Mg_3N_2	magnesium nitride	(3)
Phosphorus and fluorine	covalent	PF_3	Phosphorus trifluoride	(3)

Unit Exercise (p. 134)

24 Classify each of the following compounds as ionic or covalent. Give the chemical formula of each compound.

Compound	Ionic / covalent	Chemical formula	
Ammonia	covalent	NH_3	(2)
Copper(II) sulphate	ionic	$CuSO_4$	(2)
Hydrogen iodide	covalent	HI	(2)
Sulphur trioxide	covalent	SO_3	(2)
Silver nitrate	ionic	$AgNO_3$	(2)

Unit Exercise (p. 134)

25 This question is about two compounds formed from fluorine and two Period 3 elements.

a) Aluminium can combine with fluorine. Ionic bonding exists in the compound formed.

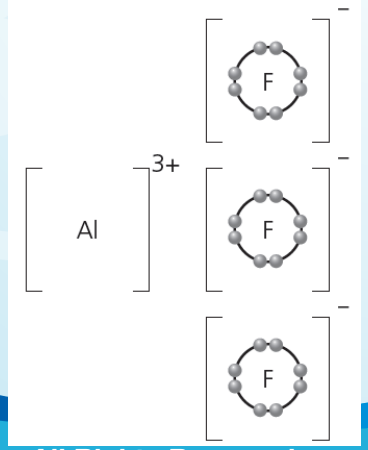
i) What is meant by the term 'ionic bonding'?

An ionic bond is the strong electrostatic forces of attraction between oppositely charged ions. (1)

ii) Draw the electron diagram for the compound, showing electrons in the *outermost shells* only.

iii) Give the name and chemical formula of the compound.

ii)



(1)

iii) Aluminium fluoride (1)

AlF_3 (1)

Unit Exercise (p. 134)

b) Silicon can combine with fluorine. Covalent bonding exists in the compound formed.

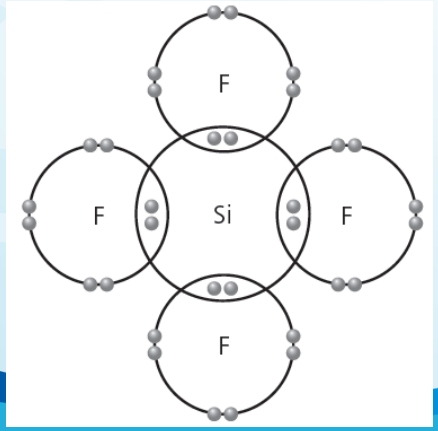
i) What is meant by the term 'covalent bonding'?

A covalent bond is the electrostatic forces of attraction between the positively charged nuclei of the two bonded atoms and the negatively charged shared electrons. (1)

ii) Draw the electron diagram for the compound, showing electrons in the *outermost shells* only.

iii) Give the name and chemical formula of the compound.

ii)



(1)

iii) Silicon tetrafluoride (1)
SiF_4 (1)

Unit Exercise (p. 134)

26 The table shows some physical properties of Group VII elements.

Element	Melting point (°C)	Boiling point (°C)	Colour
Fluorine	−220	−190	pale yellow
Chlorine	−101	−34	?
Bromine	−7	58	reddish brown
Iodine	113	184	black

a) Use the information in the table to explain why

i) chlorine is a gas at room temperature;

The boiling point of chlorine is below room temperature. (1)

ii) bromine is a liquid at room temperature.

The melting point of bromine is below room temperature but its boiling point is above room temperature. (1)

b) Why is the formula of fluorine always written as F_2?

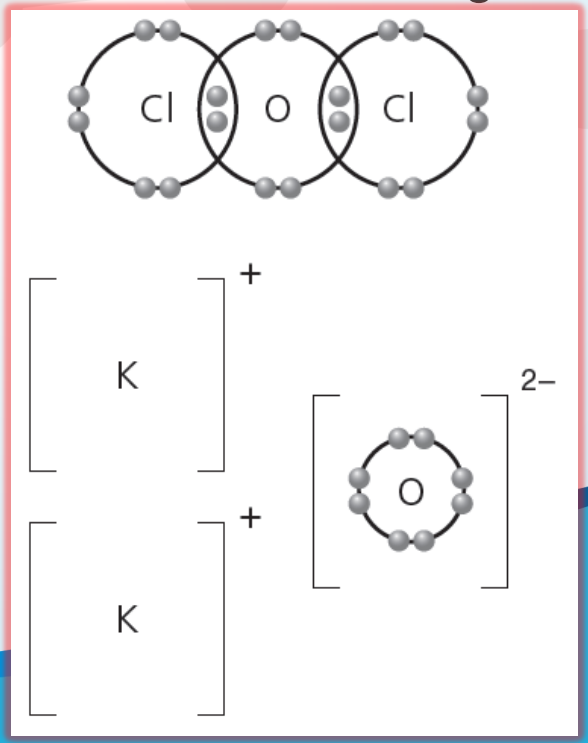
Two fluorine atoms share a pair of electrons in their outermost shells to make a fluorine molecule, F_2. (1)

Unit Exercise (p. 134)

c) Bromine reacts with fluorine to form bromine trifluoride (BrF_3). Calculate the relative molecular mass of bromine trifluoride.
(Relative atomic masses: F = 19.0, Br = 79.9)

79.9 + 3 x 19.0 = 136.9 (1)

d) Chlorine forms an oxide with the chemical formula Cl_2O while potassium forms an oxide with the chemical formula K_2O.
Draw an electron diagram for each oxide, showing electrons in the *outermost shells* only.



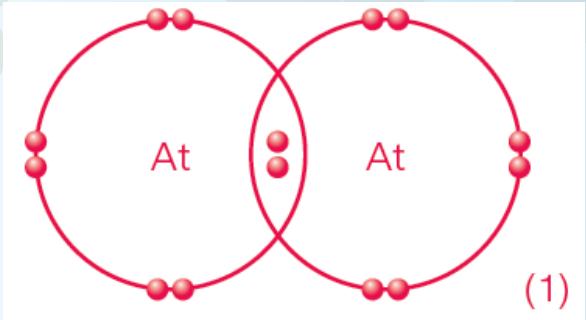
(1)

(1)

Unit Exercise (p. 134)

27 Astatine, At, is an element in Group VII of the Periodic Table.

a) Astatine forms a diatomic molecule with the same type of bonding as in a chlorine molecule.
Draw the electron diagram for an astatine molecule.
Only draw the *outermost shell* electrons.



b) Astatine reacts with magnesium to form magnesium astatide, $MgAt_2$, which contains Mg^{2+} and At^- ions.
Describe how a magnesium ion and an astatide ion are formed from a magnesium atom and an astatine atom.

(Cambridge GCE O Level, Paper 2, 5070/22, Jun. 2014, B10(b)–(c)(i))

A magnesium atom loses two electrons to form a magnesium ion. (1)
An astatine atom gains one electron to form an astatide ion. (1)

Unit Exercise (p. 134)

28 Describe the formation of dative covalent bond using H_3O^+ as example.
(HKDSE, Paper 1B, 2017, 3(c))

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).

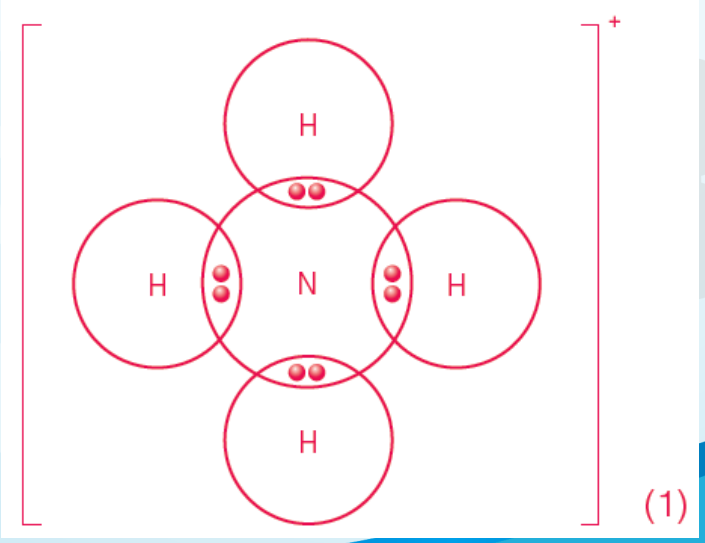
Unit Exercise (p. 134)

29 On mixing with water, ammonia reacts to form an alkaline solution containing ammonium ions and hydroxide ions. The ammonium ion has dative covalent bonding.

a) Explain the term 'dative covalent bonding'.

A dative covalent bond is a type of covalent bond in which both electrons come from the same atom. (1)

b) Draw the electron diagram for the ammonium ion, showing electrons in the *outermost shells* only.



Unit Exercise (p. 134)

30 The following is a part of the Periodic Table.

		H				He
Li	Be		B	C	N	O	F	Ne
Na	Mg		Al	Si	P	S	Cl	Ar
K	Ca							

a) How many electrons do atoms of neon and argon have in their outermost shells? 8 (1)

b) Suggest how argon could be extracted from liquid air.

Fractional distillation of liquid air (1)

c) What key property can you tell about fluorine from its position in the Periodic Table?

A fluorine atom gains one electron to form a fluoride ion. (1)

d) What type of bonding would you expect to find in each of the following compounds? Explain your answers.

i) Methane (CH_4) Covalent bonding (1) Both carbon and hydrogen are non-metals. They combine to form a covalent compound. (1)

ii) Calcium chloride ($CaCl_2$)

Ionic bonding (1) Calcium is a metal while chlorine is a non-metal. They combine to form ionic compound. (1)

Unit Exercise (p. 134)

31 Describe what happen, in terms of electron transfer or sharing, when sulphur atoms combine separately with hydrogen atoms and potassium atoms.

A sulphur atom has an electronic arrangement of 2,8,6 while a hydrogen atom has an electronic arrangement of 1.

A sulphur atom shares a pair of electrons with each of two hydrogen atoms to make a hydrogen sulphide molecule (H_2S). Now, all the atoms get the electronic arrangements of atoms of noble gases. (1)

A potassium atom has an electronic arrangement of 2,8,8,1.

When potassium and sulphur react to form potassium sulphide (K_2S), one electron from each of two potassium atoms is transferred to one sulphur atom. (1)

Communication mark (1)

Unit Exercise (p. 134)

32 The following is a list of electronic arrangement of atoms of some unknown elements.

Element	Electronic arrangement of atom
A	2,8,4
B	2,8,5
C	2,8,8,1
D	2,8,18,7
E	2,8,18,8
F	2,8,18,8,2

Unit Exercise (p. 134)

a) Choose an element from the list for each of the following descriptions.

i) It is a noble gas. E (1)

ii) It is a soft metal with a low density. C (1)

iii) It is a metalloid. A (1)

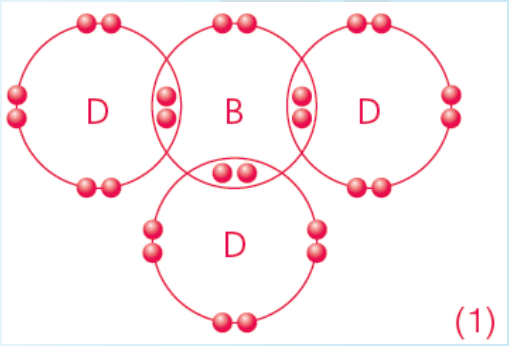
iv) It can form a positive ion of the type X^+. C (1)

b) Elements B and D combine to form compound X.

i) Explain whether compound X is ionic or covalent.

Both elements B and D are non-metals. They combine to form a covalent compound. (1)

ii) Draw the electron diagram for compound X, showing electrons in the *outermost shells* only.

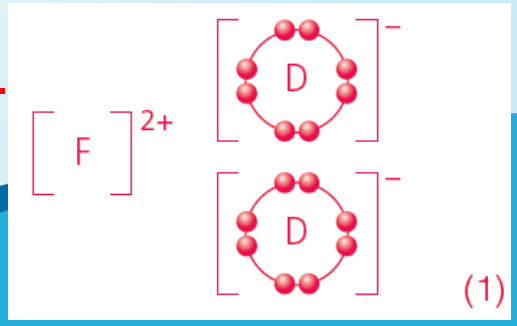


c) Elements D and F combine to form compound Y.

i) Explain whether compound Y is ionic or covalent.

Element D is a non-metal while element F is a metal. They combine to form an ionic compound. (1)

ii) Draw the electron diagram for compound Y, showing electrons in the *outermost shells* only.



Unit Exercise (p. 134)

33 Space probes have been sent to Mars to analyse the soil.

a) One compound analysed has the chemical formula $Ca(ClO_4)_2$.
Calculate its formula mass.
(Relative atomic masses: O = 16.0, Cl = 35.5, Ca = 40.1)

$40.1 + 2 \times 35.5 + 8 \times 16.0 = 239.1$ (1)

b) Another compound found on Mars has the molecular formula C_4H_{10}.
Calculate its relative molecular mass.
(Relative atomic masses: H = 1.0, C = 12.0)

$4 \times 12.0 + 10 \times 1.0 = 58.0$ (1)