Chemical Bonding for Lower Secondary Science

Chemical Bonding

Introduction

1. Why do the atoms of the different chemical elements *react* and *bond together* ?

Chemical Bonding

Introduction

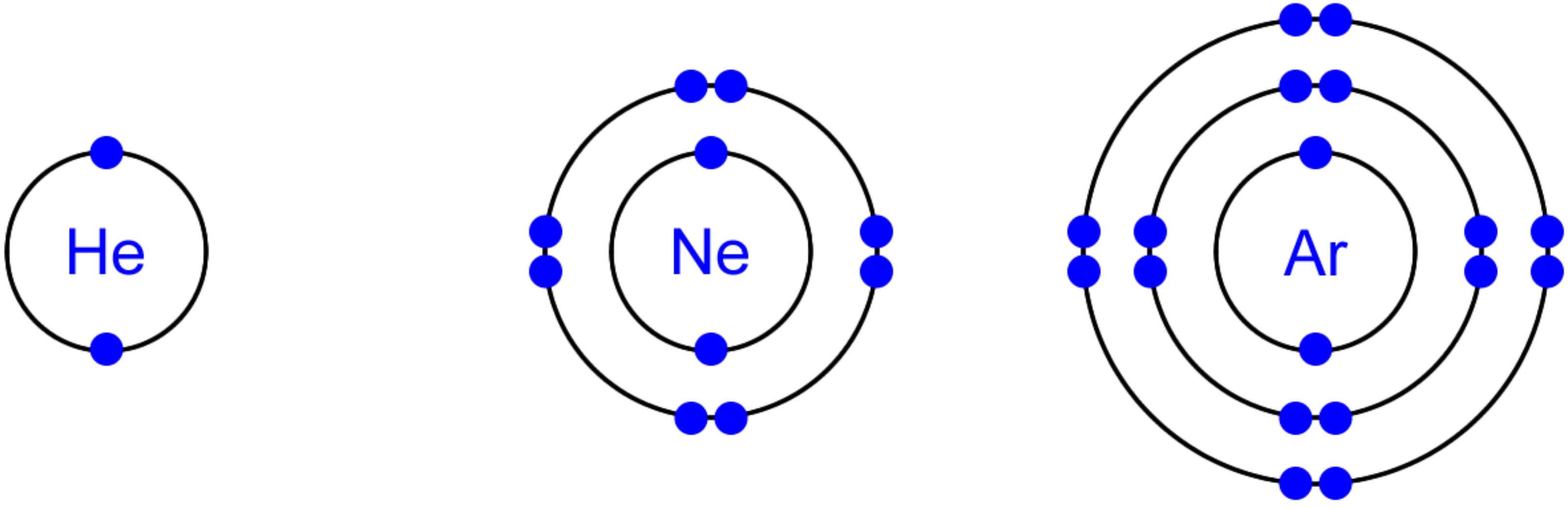
Essential Understanding

- During the formation of a chemical bond, atoms combine together by gaining, losing or sharing electrons in such a way that they acquire the electronic configuration of the nearest noble gas.

Chemical Bonding

Introduction

- Helium, neon and argon are noble gases which are all inert (unreactive) chemical elements.

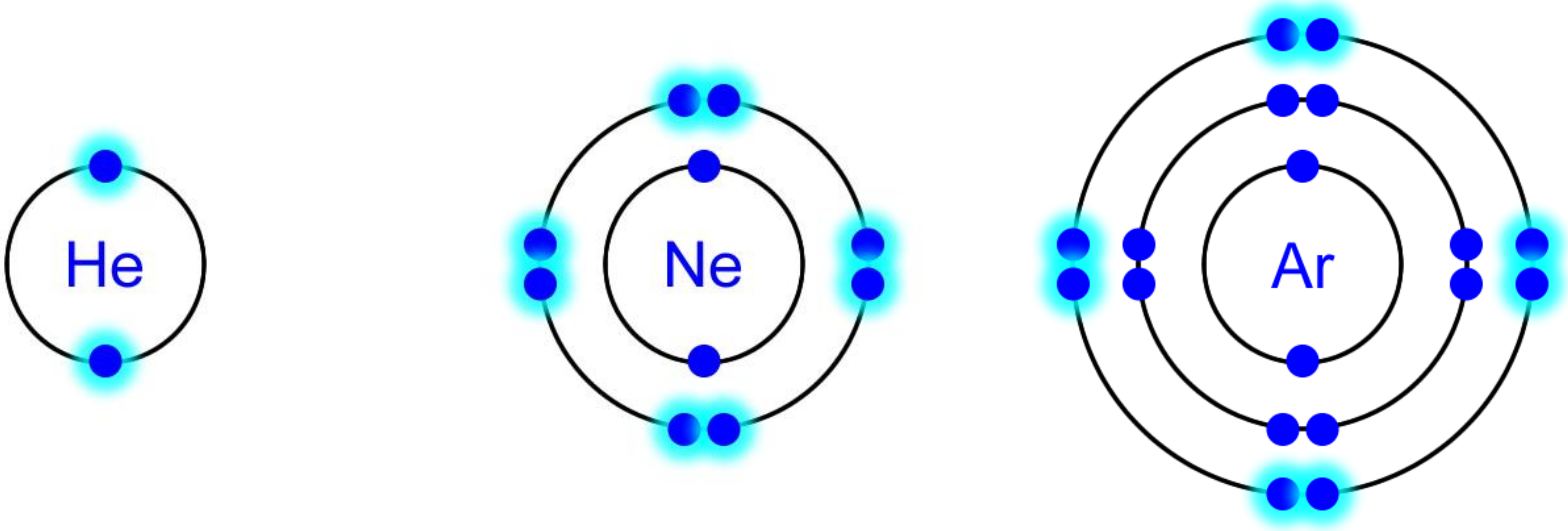


- What do their electronic configurations all have in common?
- What aspect of their electronic configurations could cause them to be so unreactive?

Chemical Bonding

Introduction

- Helium, neon and argon are noble gases which are all inert (unreactive) chemical elements.



- They all have *complete* (full) *valence shells*.
- Complete valence shells cause the atoms of helium, neon and argon to be *stable*, *low energy* and hence *unreactive*.

Chemical Bonding

Introduction

- Unlike helium, neon and argon, sodium is a very reactive chemical element.

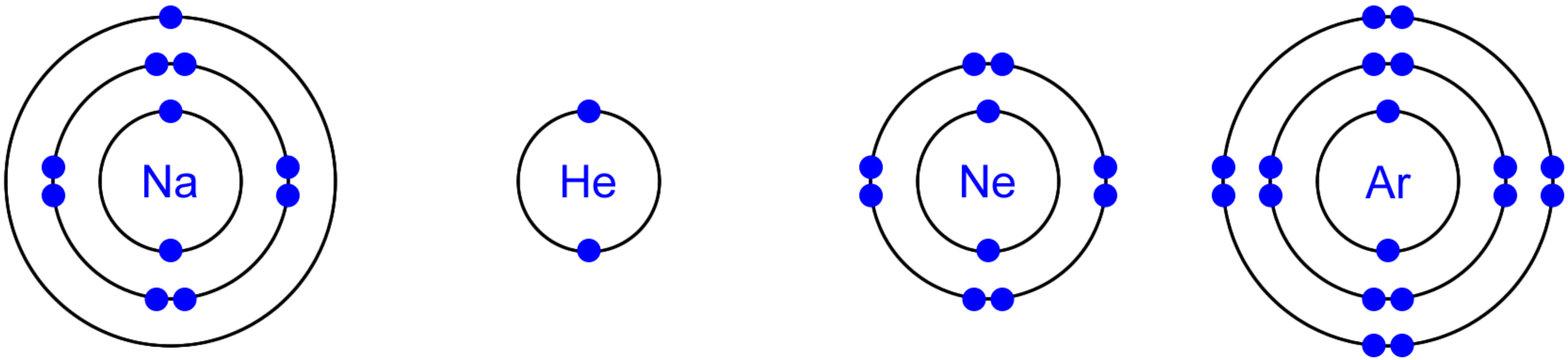
Sodium metal reacting with water at room temperature:

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

Chemical Bonding

Introduction

- Unlike helium, neon and argon, sodium is a very reactive chemical element.

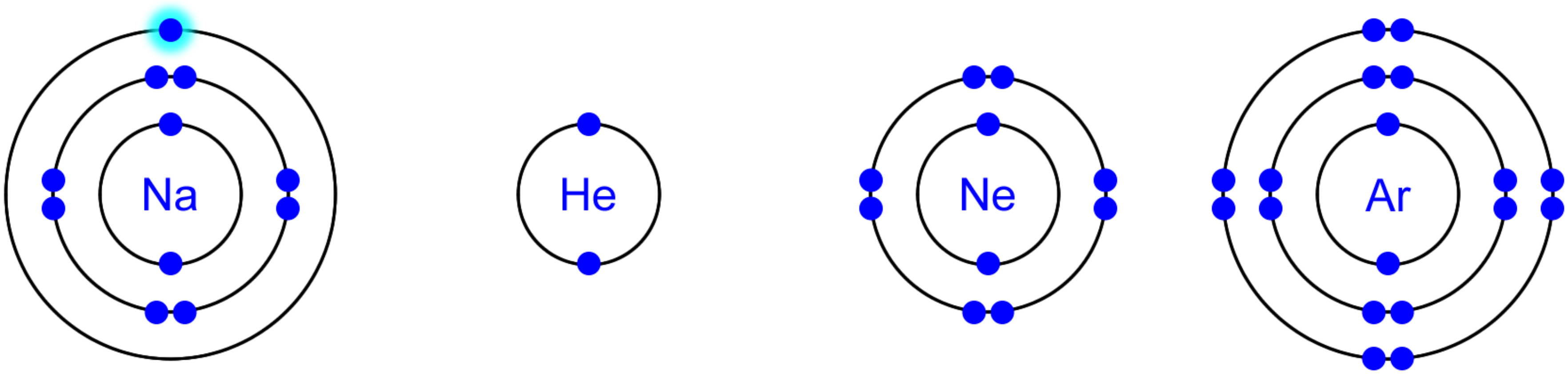


- In what way(s) is sodium's electronic configuration different to that of helium, neon and argon?
- Why is sodium a reactive chemical element?
- What do atoms of sodium achieve by reacting?

Chemical Bonding

Introduction

- Unlike helium, neon and argon, sodium is a very reactive chemical element.

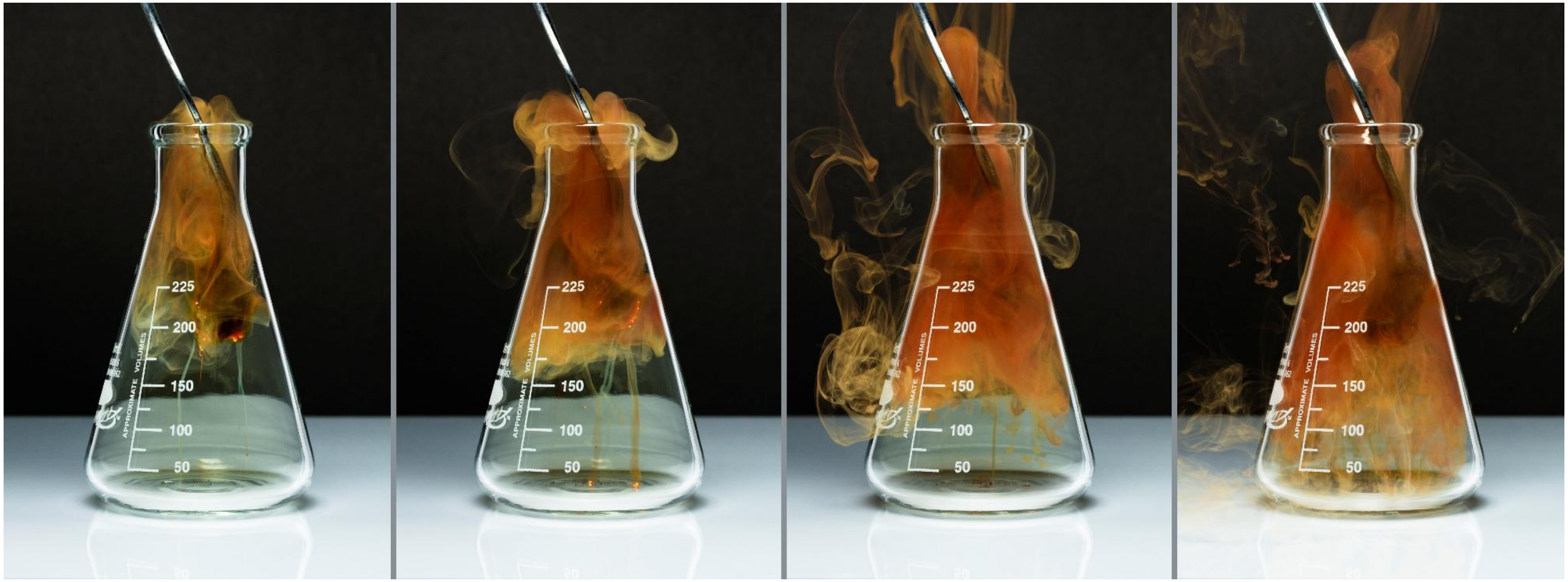


- A sodium atom has an *incomplete* valence shell.
- Due to its incomplete valence shell, a sodium atom is relatively *unstable*, *high energy* and hence *reactive*.
- A sodium atom will react in order to obtain a *noble gas electronic configuration*.

Chemical Bonding

Introduction

- Unlike helium, neon and argon, chlorine is a very reactive chemical element.



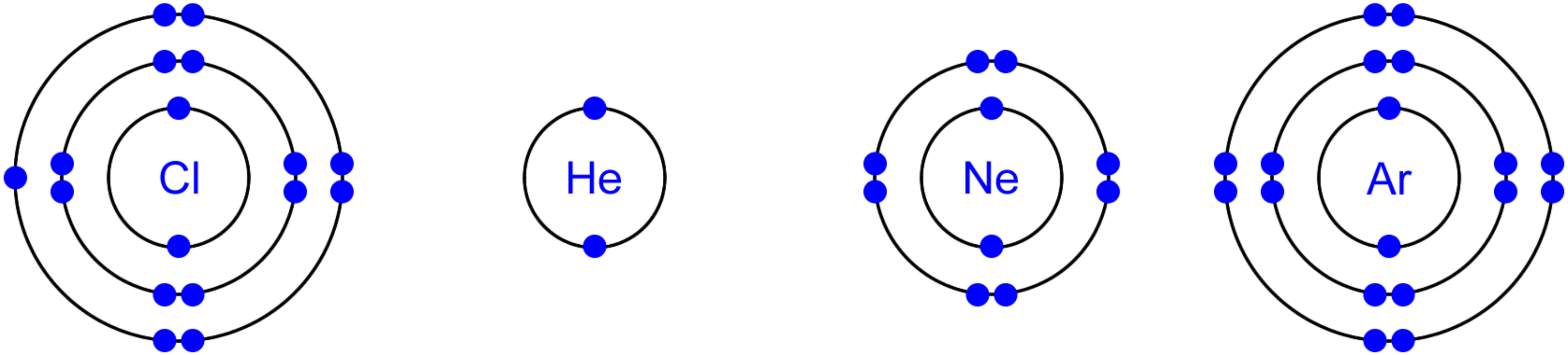
Iron wool reacting with chlorine gas at room temperature:

$2Fe_{(s)} + 3Cl_{2(g)} \rightarrow 2FeCl_{3(s)}$

Chemical Bonding

Introduction

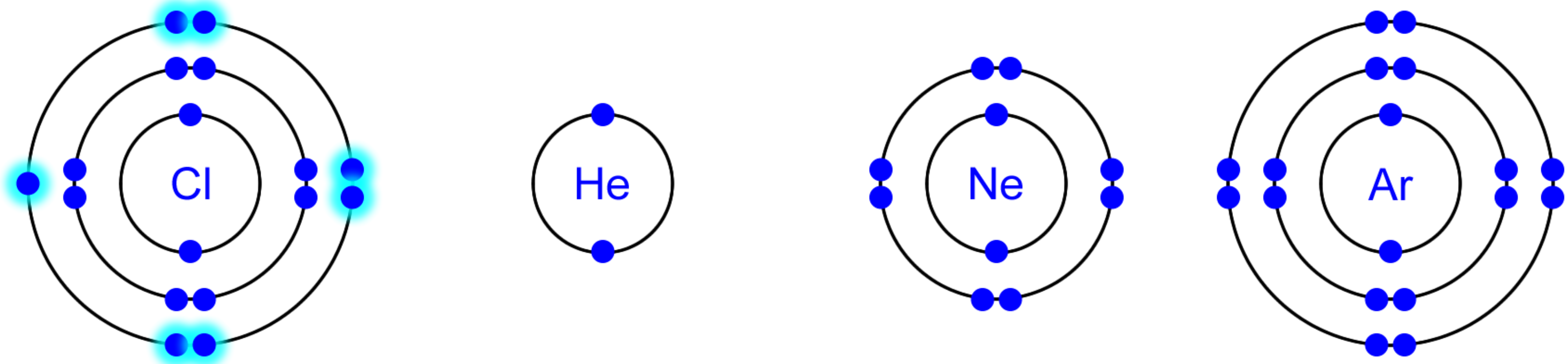
- Unlike helium, neon and argon, chlorine is a very reactive chemical element.



- In what way(s) is chlorine's electronic configuration different to that of helium, neon and argon?
- Why is chlorine a reactive chemical element?
- What do atoms of chlorine achieve by reacting?

Chemical Bonding
Introduction

- Unlike helium, neon and argon, chlorine is a very reactive chemical element.



- A chlorine atom has an *incomplete* valence shell.
- Due to its incomplete valence shell, a chlorine atom is relatively *unstable*, *high energy* and hence *reactive*.
- A chlorine atom will react in order to obtain a *noble gas electronic configuration*.

Chemical Bonding

Introduction

- We will see how *sodium* and *chlorine* react to form a compound in which particles of each chemical element have stable electronic configurations shortly.

Chemical Bonding

Introduction

Objective of chemical bonding:

- At the end of a chemical reaction, all of the atoms or ions that are present *will have noble gas electronic configurations*, *i.e.* the outermost electron shell of every atom or ion must be filled with its maximum number of electrons.

  - Inner electron shell = 2.
  - Second Electron Shell = 8.
  - Third Electron Shell = 8.

- By obtaining a noble gas electronic configuration, the atom of the chemical element becomes a *stable*, *low energy* particle.

Chemical Bonding

Introduction

There are three different types of chemical bonding:

- Ionic bonding (metal and non-metal).
- Covalent bonding (two or more non-metals).
- Metallic bonding.

Note: It is very important to remember that chemical bonding only involves rearranging an atom's *valence shell electrons*. The numbers of protons and neutrons in the nucleus of the atom are not affected by chemical bonding.

Chemical Bonding

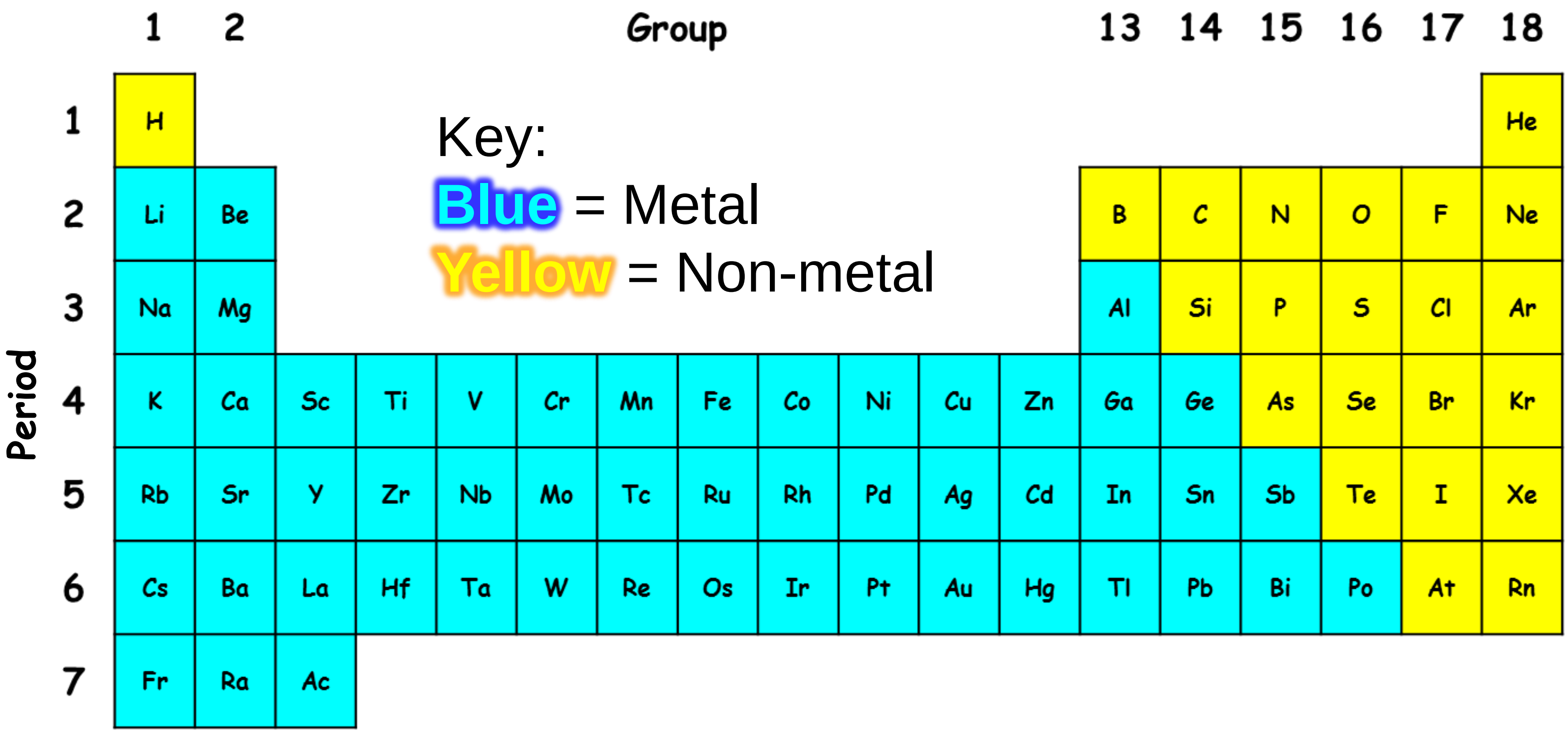
Ionic Bonding – Metals and Non-metals

2. How do the atoms of a *metallic chemical element* and a *non-metallic chemical elements* react together to obtain noble gas electronic configurations?

Chemical Bonding

Ionic Bonding – Metals and Non-metals

- Ionic bonding occurs in compounds that are formed when a *metal* reacts with a *non-metal*.



Chemical Bonding

Ionic Bonding – Sodium Chloride

- The reaction between sodium and chlorine to form sodium chloride. Sodium is a very reactive metal and chlorine is a very reactive non-metal, yet the product of their reaction – sodium chloride – is safe enough to eat.

Sodium metal reacting chlorine gas at room temperature:

$$2Na_{(s)} + Cl_{2(g)} \quad 2NaCl_{(s)}$$

Chemical Bonding

Ionic Bonding – Sodium Chloride

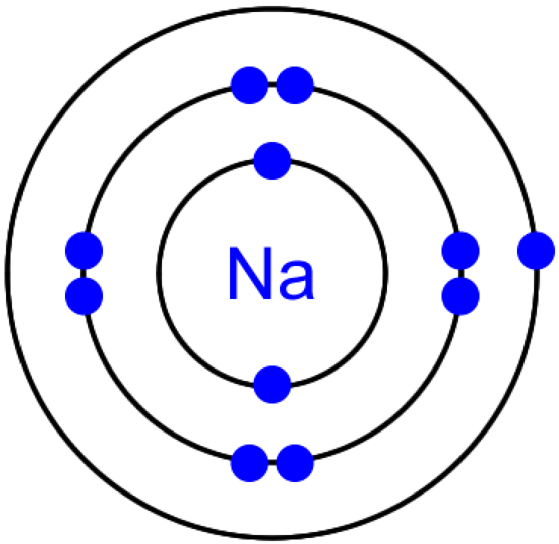
- Notice that the reaction between sodium and chlorine is highly *exothermic*, *i.e.* energy is lost to the surroundings as the sodium atoms and chlorine atoms react to obtain noble gas electronic configurations and become more stable.

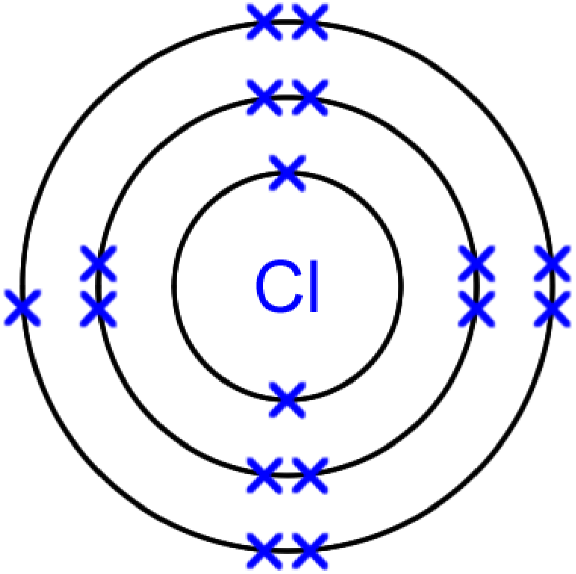
Sodium metal reacting chlorine gas at room temperature:

$2Na_{(s)} + Cl_{2(g)} \quad 2NaCl_{(s)}$

Chemical Bonding

Ionic Bonding – Sodium Chloride



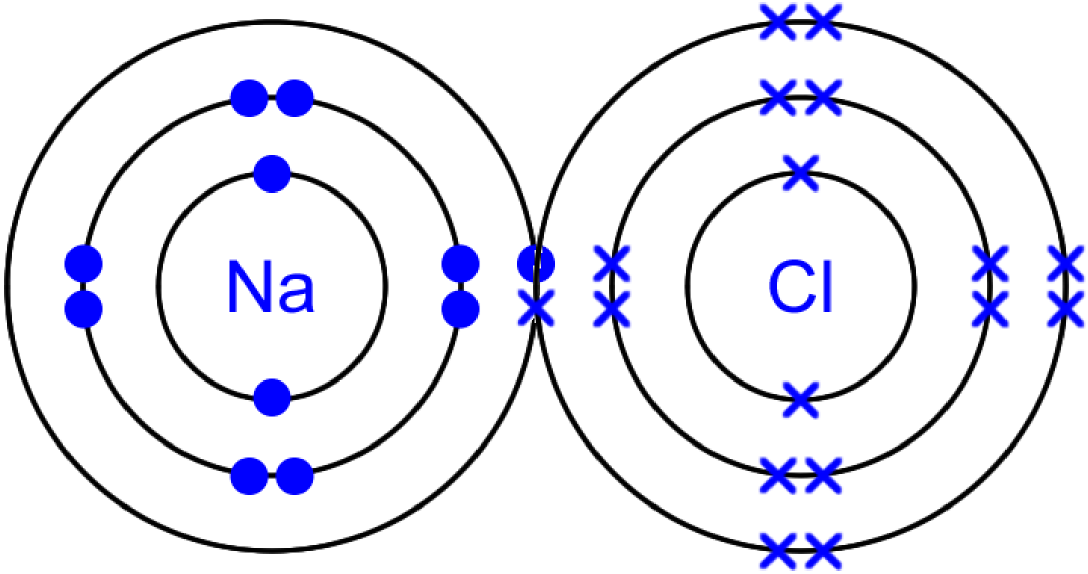


- Can an atom of sodium and an atom of chlorine *both* obtain noble gas electronic configurations by *sharing electrons*?

• = Electron of sodium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Sodium Chloride



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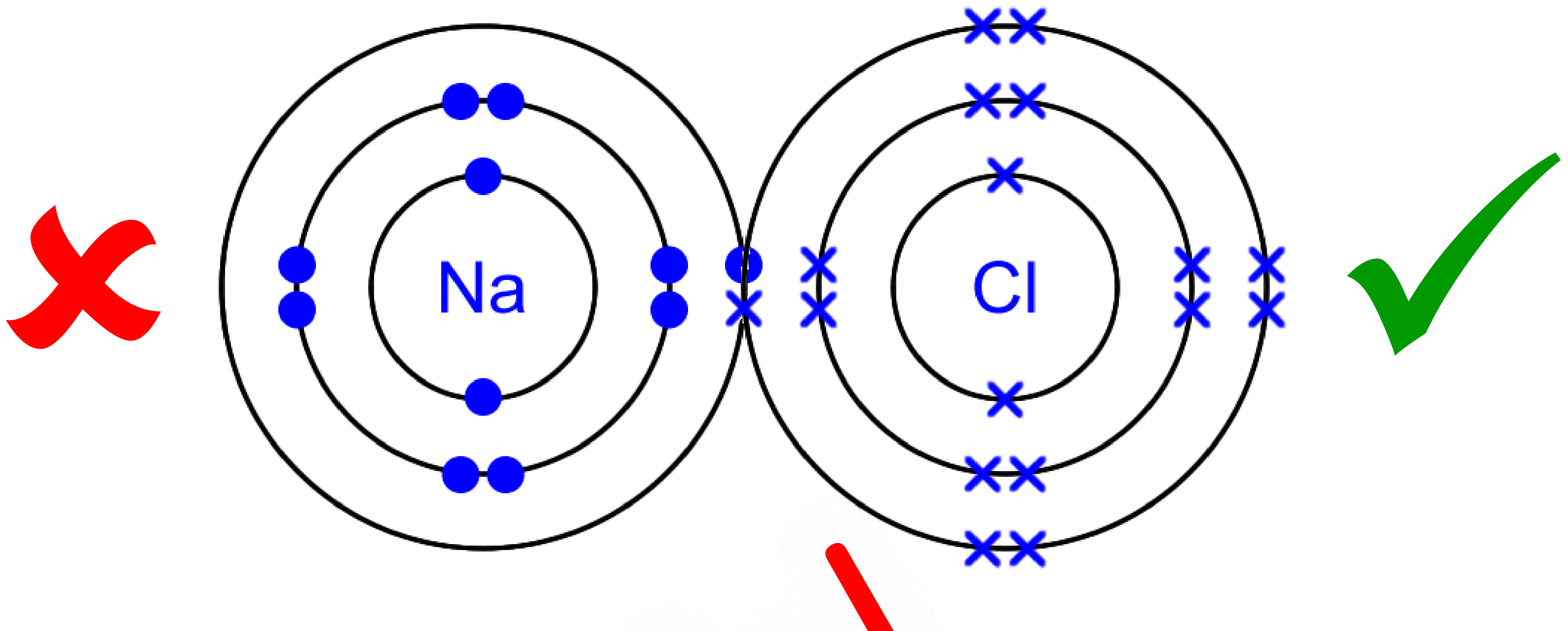
Chemical Bonding

Ionic Bonding – Sodium Chloride



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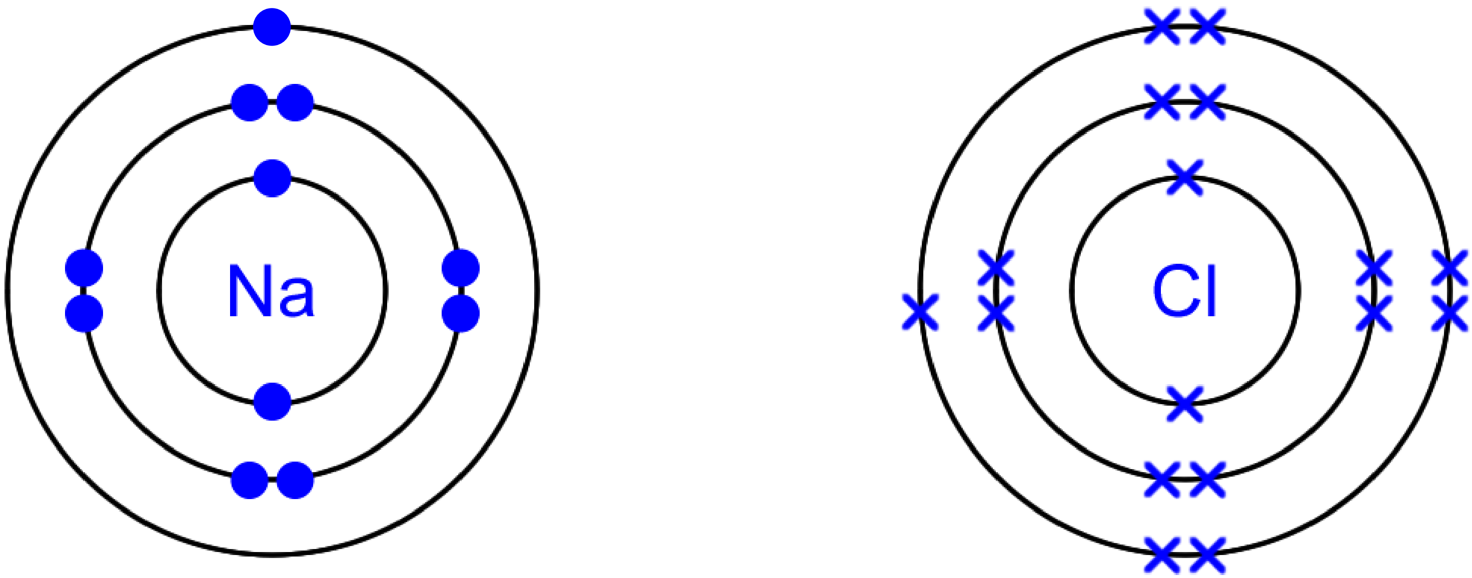
Chemical Bonding

Ionic Bonding – Sodium Chloride

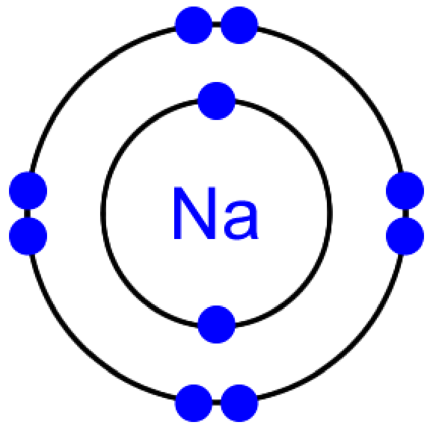


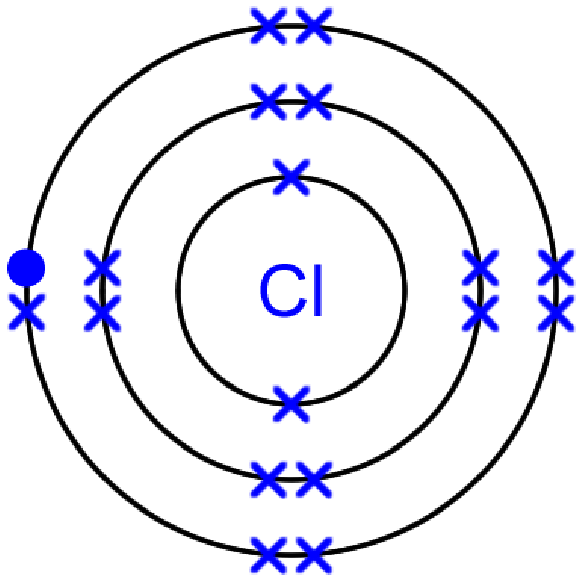
- In ionic bonding, the atom of the metallic element *transfers* it valence electron(s) into the valence shell of the non-metallic element.

• = Electron of sodium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Sodium Chloride





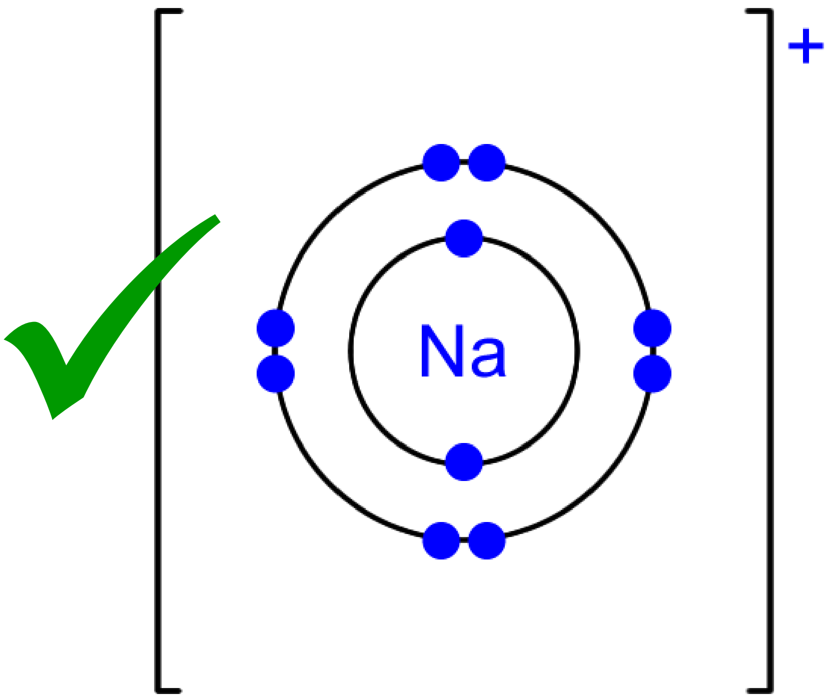
- In ionic bonding, the atom of the metallic element *transfers* it valence electron(s) into the valence shell of the non-metallic element.

• = Electron of sodium.

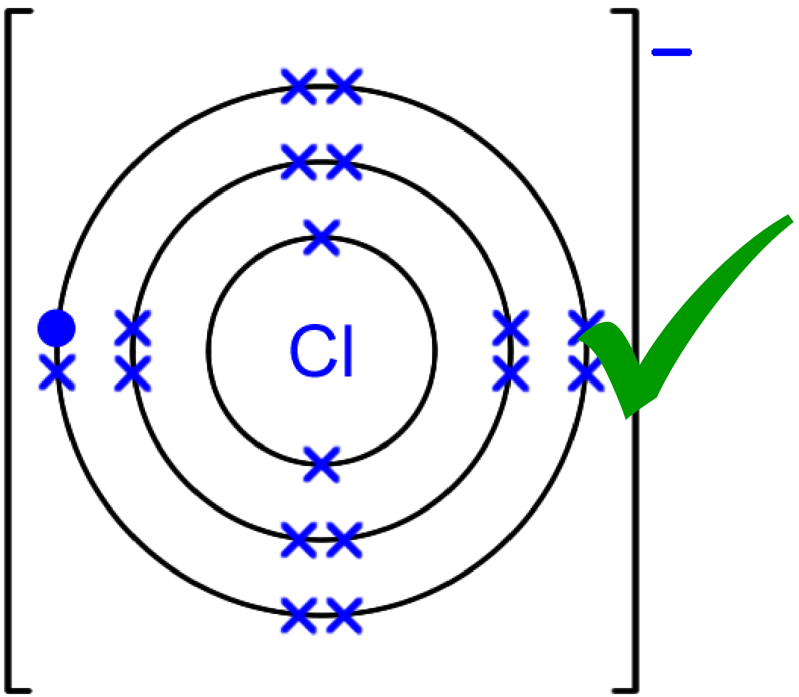
× = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Sodium Chloride – NaC*l*



Positive Sodium Ion (Cation)
- Number of Protons = 11
- Number of Electrons = 10
- Overall Charge = (+11) + (-10) = +1



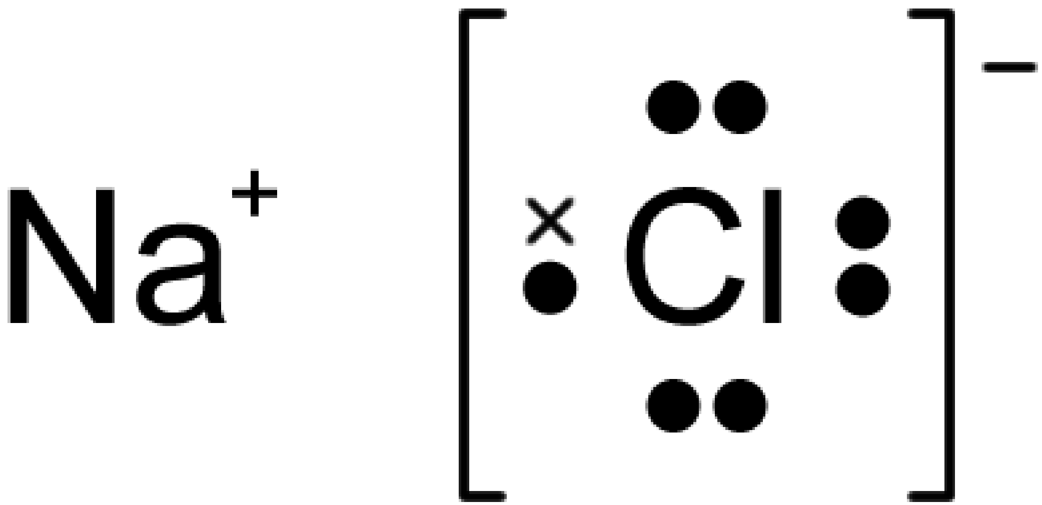
Negative Chloride Ion (Anion)
- Number of Protons = 17
- Number of Electrons = 18
- Overall Charge = (+17) + (-18) = -1

• = Electron of sodium.

× = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Sodium Chloride – NaCl

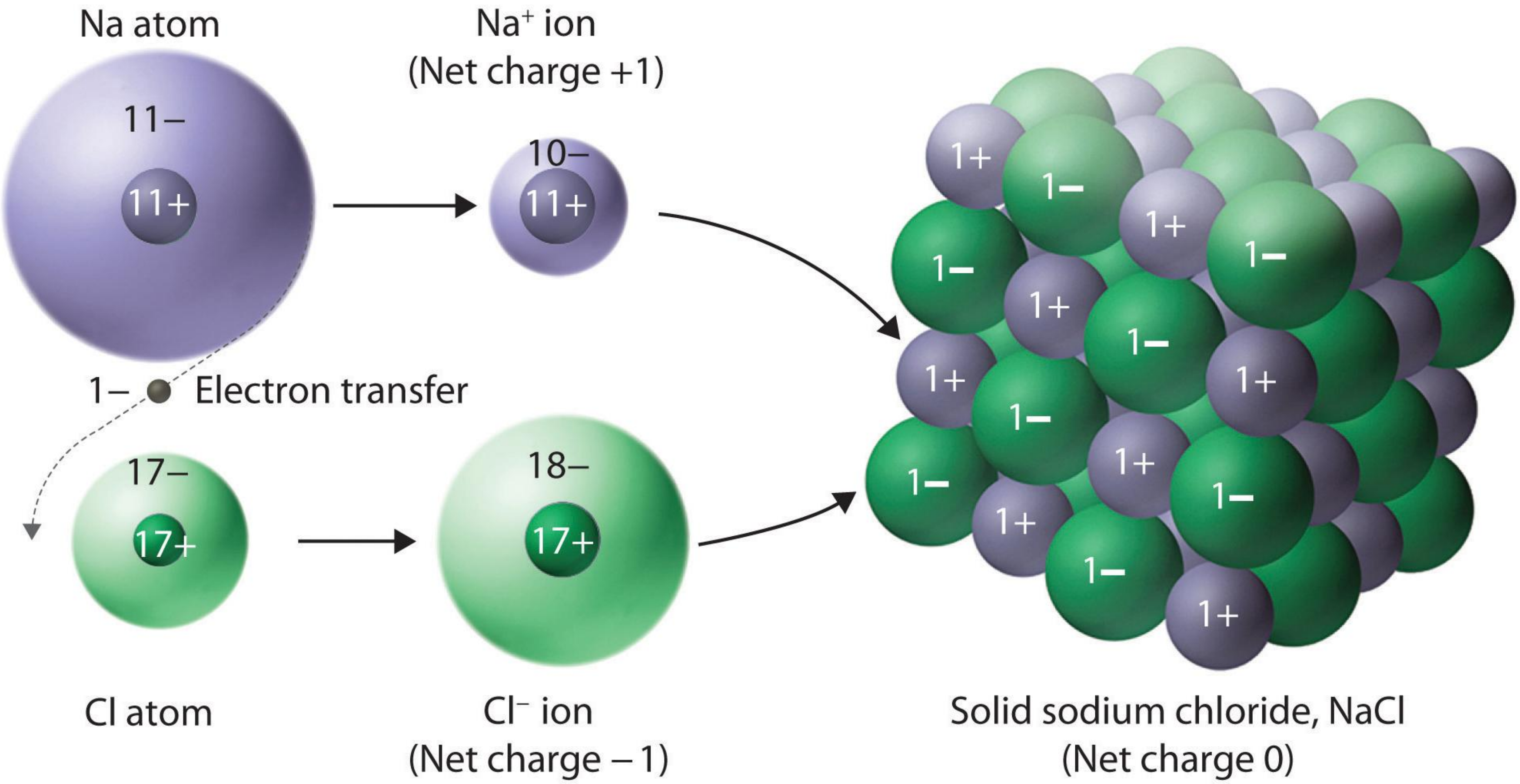


- The dot-and-cross diagram for sodium chloride that should be used as an answer in an examination.

• = Electron of chlorine. × = Electron of sodium.

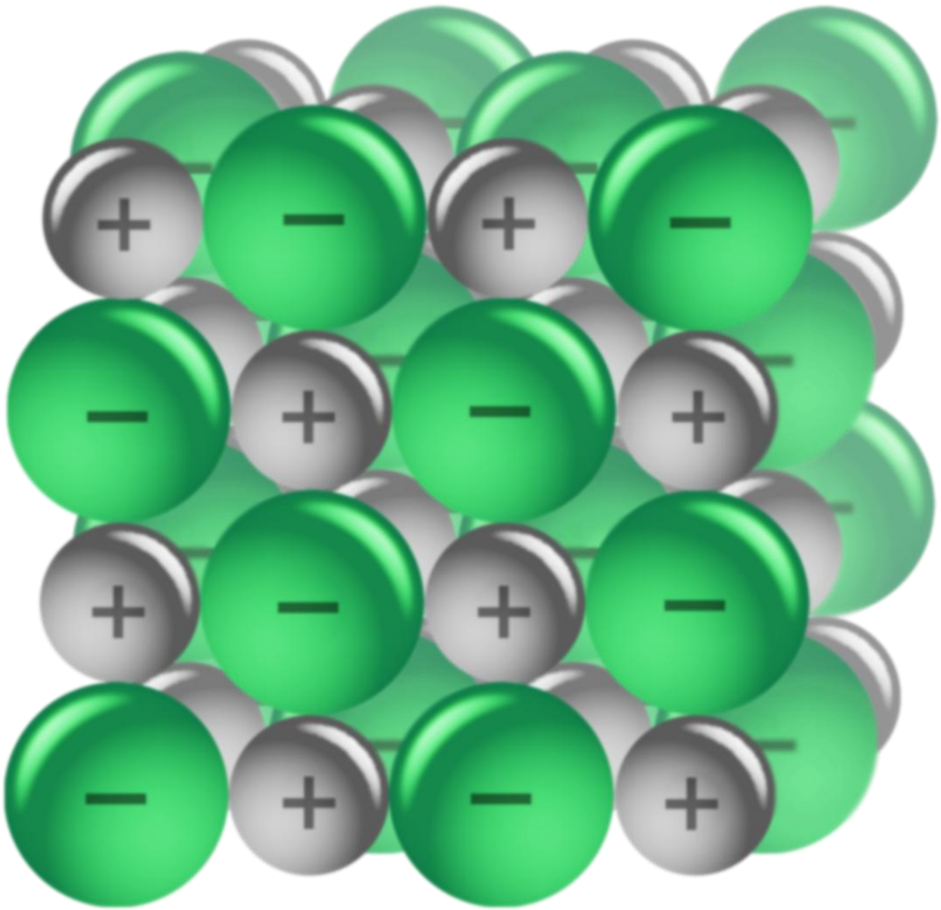
Chemical Bonding

Ionic Bonding – Sodium Chloride – NaC*l*



Chemical Bonding

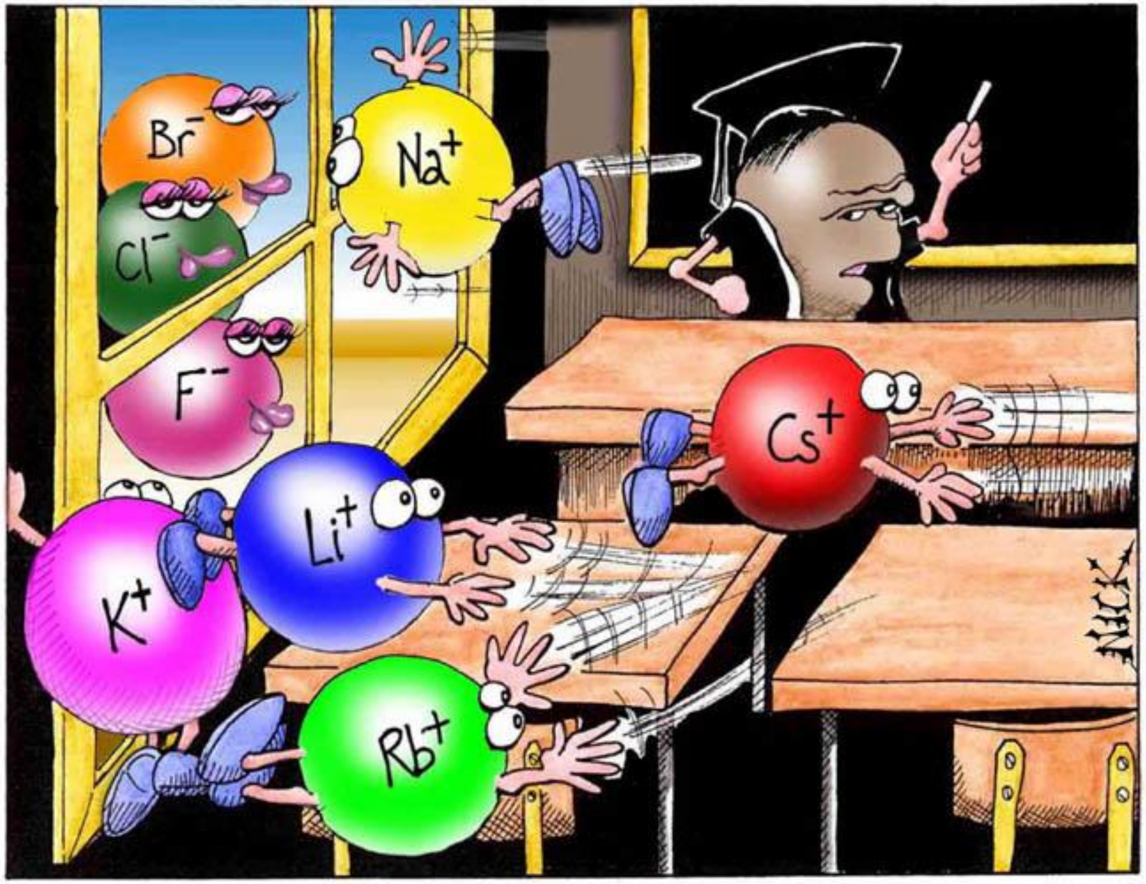
Ionic Bonding – Sodium Chloride – Na*Cl*



Ions of opposite charge are attracted towards each other in a three dimensional arrangement. A strong *electrostatic force of attraction* holds the ions together in a close packed regular arrangement known as a *crystal lattice*. Each sodium ion is surrounded by six chloride ions and vice-versa. **Note**: *Never* describe any ionic compound as a "*molecule*!"

Chemical Bonding

Ionic Bonding – Sodium Chloride – NaC*l*



"Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive..?"

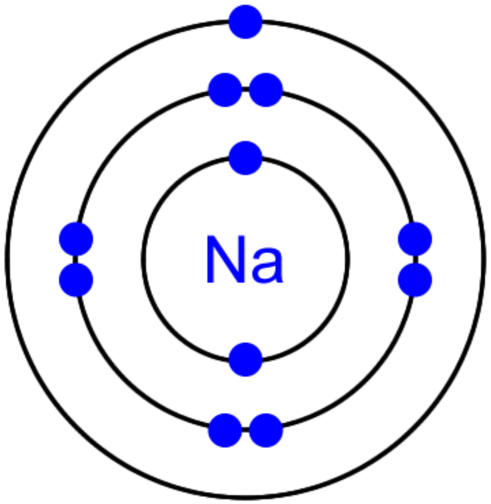
Chemical Bonding

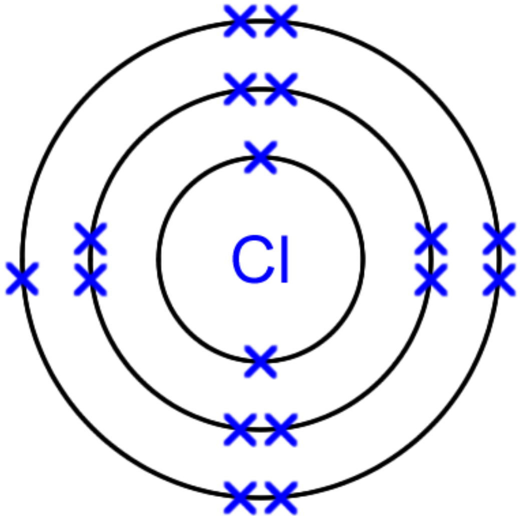
Ionic Bonding – Sodium Chloride – NaC*l*

Why are electrons transferred from the *metal* to the *non-metal* and not from the *non-metal* to the *metal*?

Chemical Bonding

Ionic Bonding – Sodium Chloride – Na*Cl*



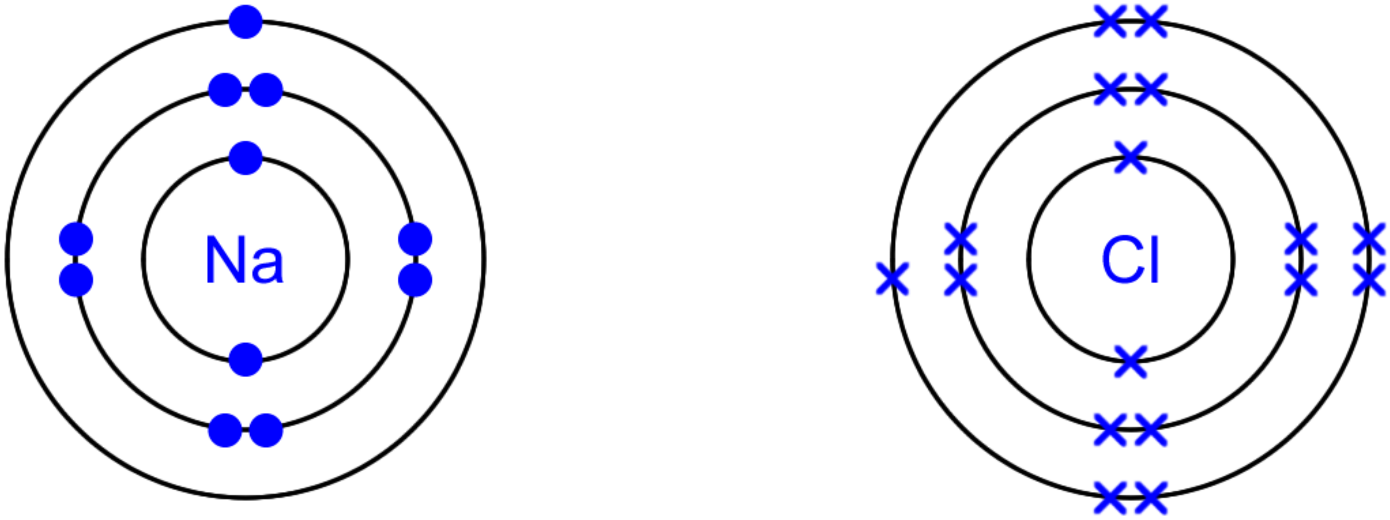


- Consider the reaction between sodium (metal) and chlorine (non-metal).

- Only *one* electron needs to be transferred from the sodium to the chlorine in order for both atoms to obtain noble gas electronic configurations.

Chemical Bonding

Ionic Bonding – Sodium Chloride – NaC*l*

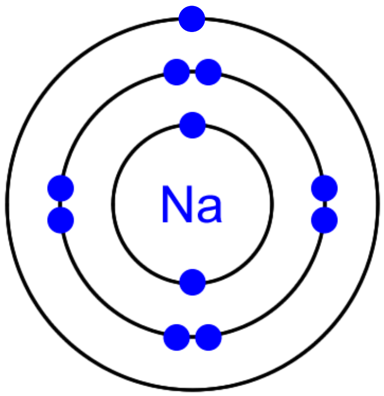


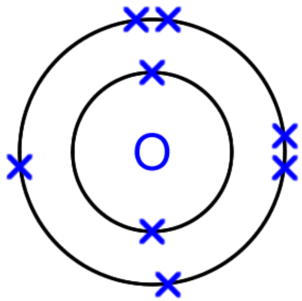
- However, *seven* electrons would need to be transferred from the chlorine to the sodium in order for both atoms to obtain a noble gas electronic configuration.

- It is easier to transfer *one* electron from sodium to chlorine compared to transferring *seven* electrons from chlorine to sodium.

Chemical Bonding

Ionic Bonding – Sodium Oxide



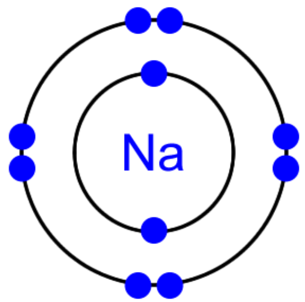


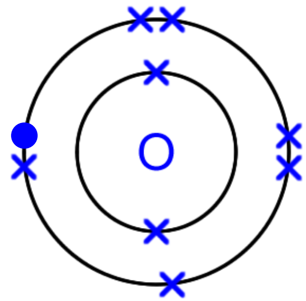
● = Electron of sodium.

× = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Sodium Oxide



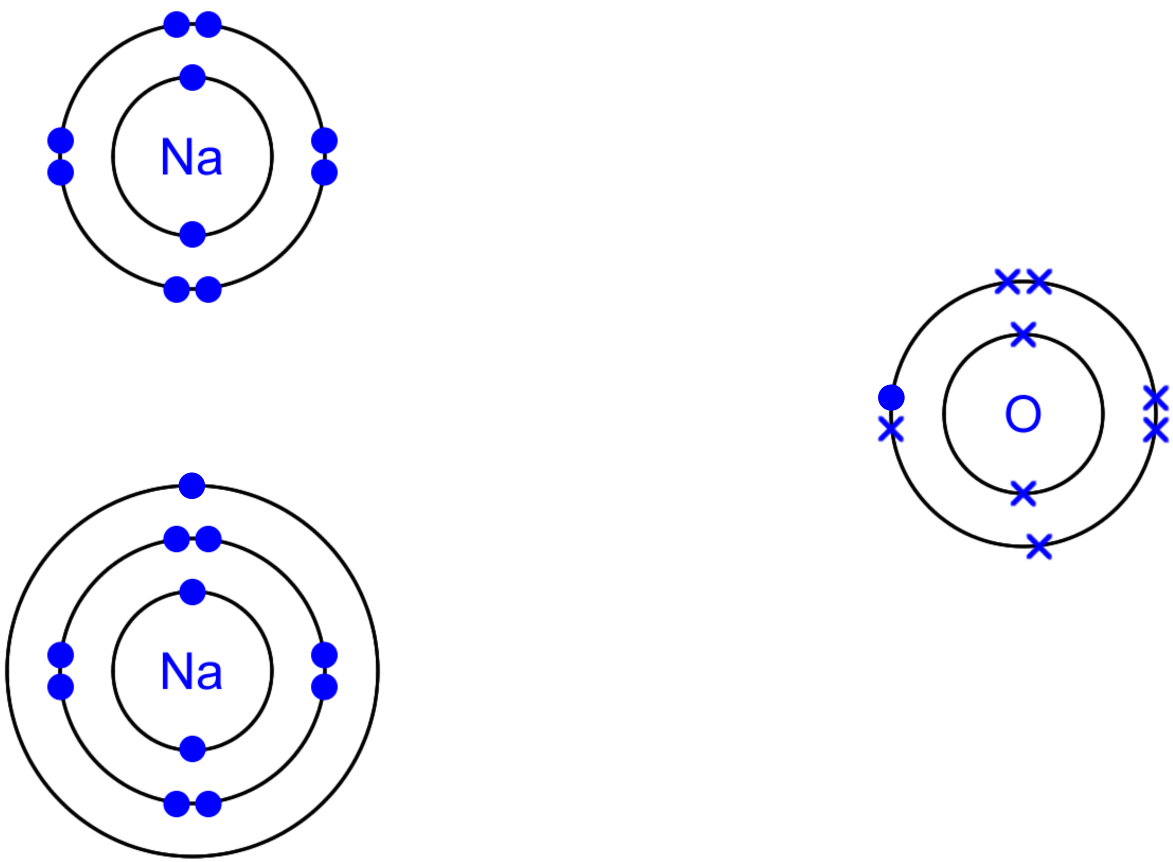


● = Electron of sodium.

× = Electron of oxygen.

Chemical Bonding

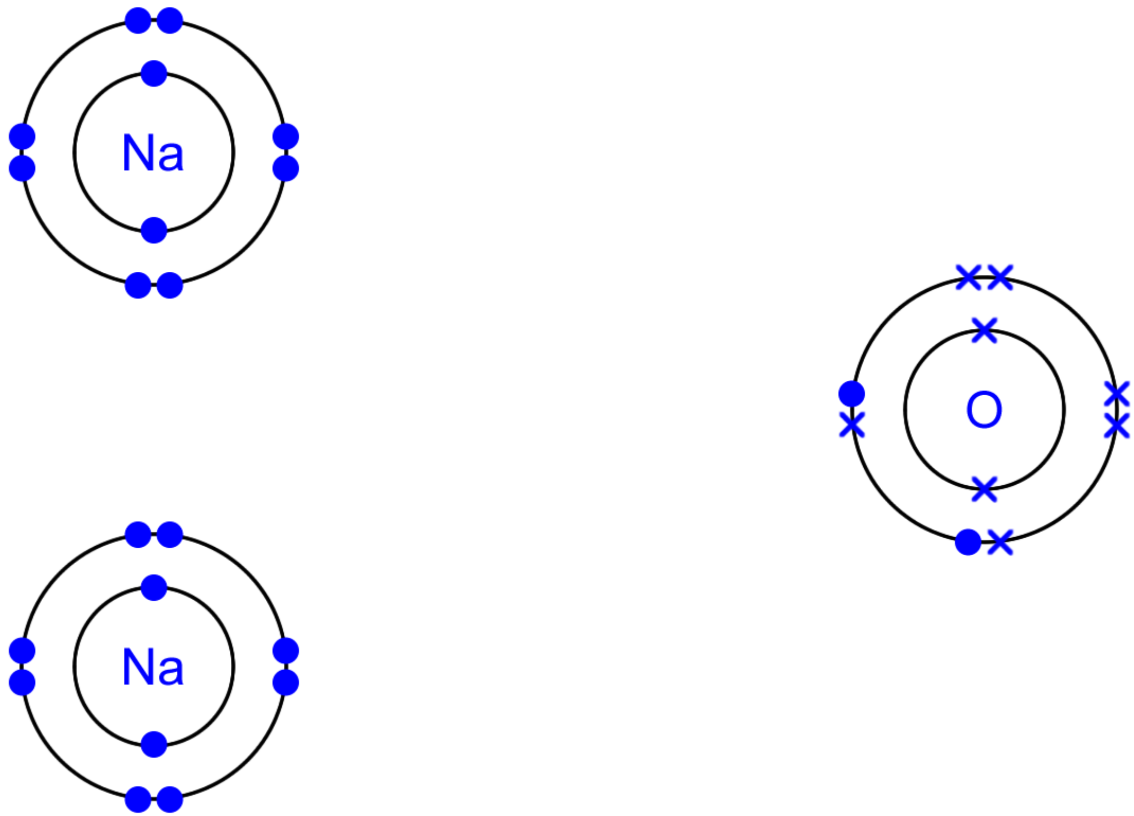
Ionic Bonding – Sodium Oxide



● = Electron of sodium.　　× = Electron of oxygen.

Chemical Bonding

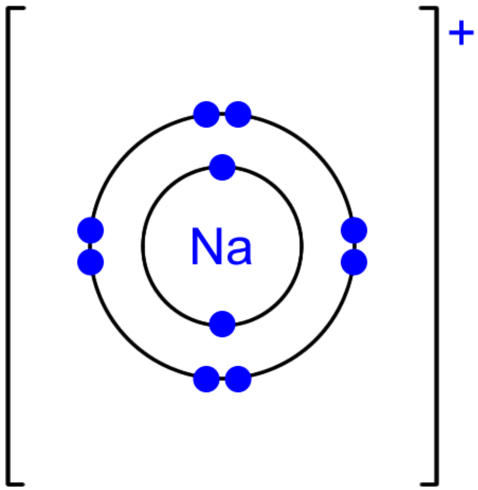
Ionic Bonding – Sodium Oxide

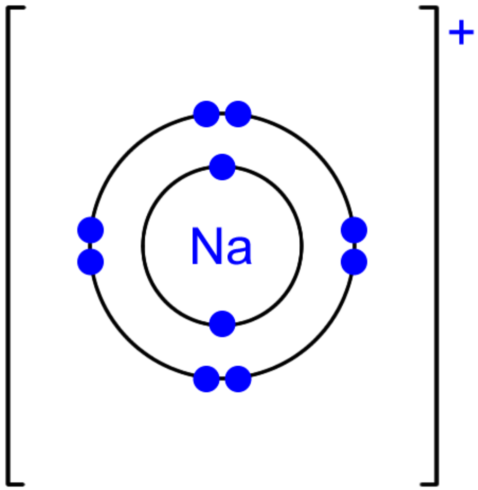


● = Electron of sodium. × = Electron of oxygen.

Chemical Bonding

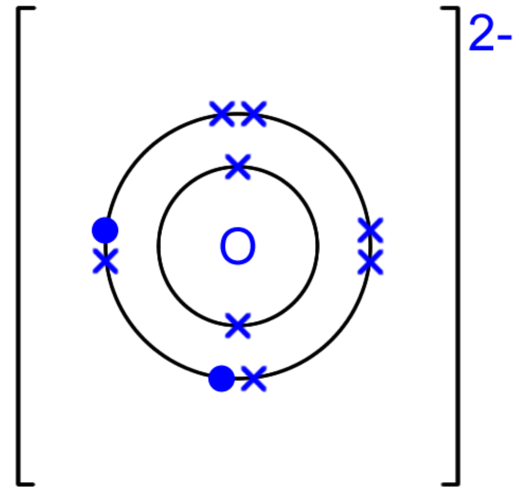
Ionic Bonding – Sodium Oxide – Na_2O





Positive Sodium Ion (Cation)

- Number of Protons = 11
- Number of Electrons = 10
- Overall Charge = (+11) + (-10) = +1



Negative Oxide Ion (Anion)

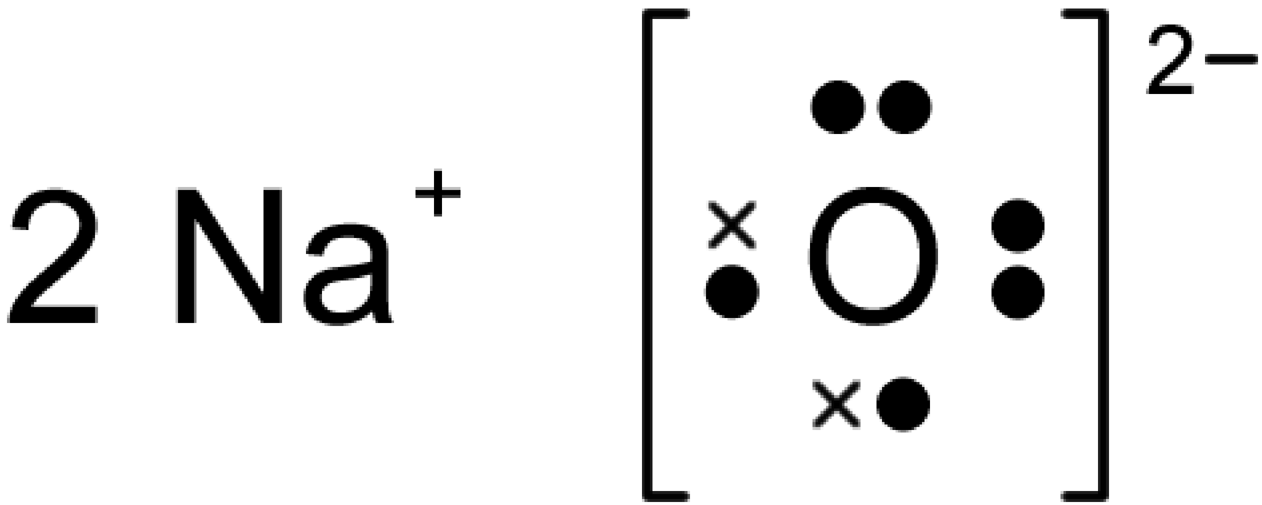
- Number of Protons = 8
- Number of Electrons = 10
- Overall Charge = (+8) + (-10) = -2

• = Electron of sodium.

× = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Sodium Oxide – Na_2O

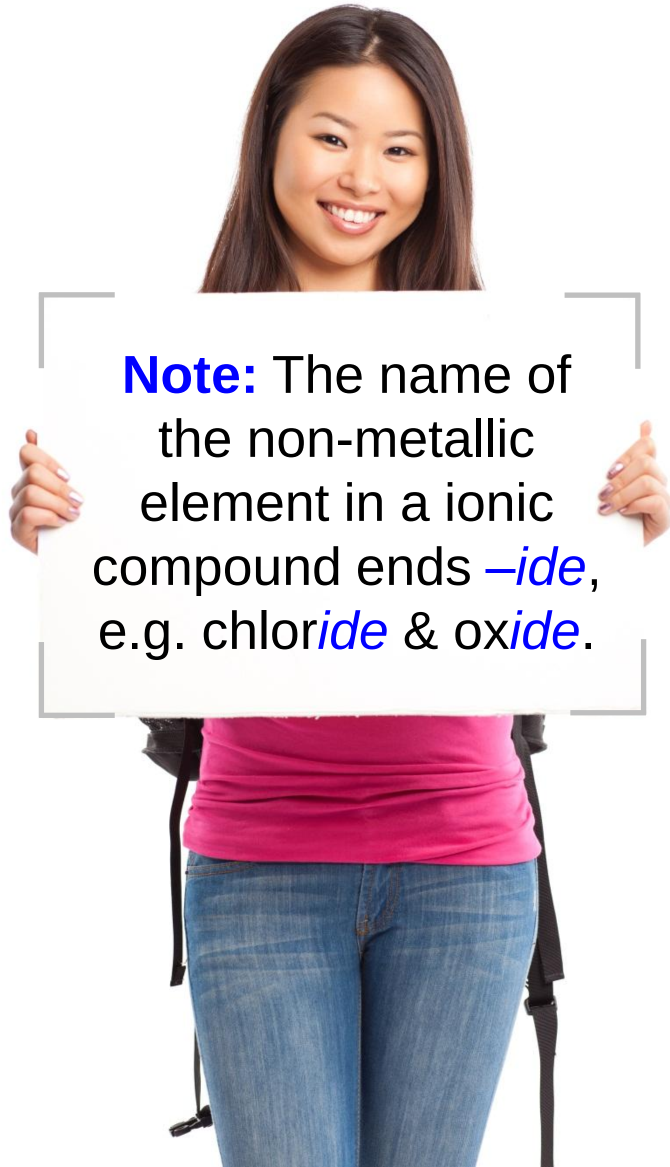


- The dot-and-cross diagram for sodium oxide that should be used as an answer in an examination.

• = Electron of oxygen. × = Electron of sodium.

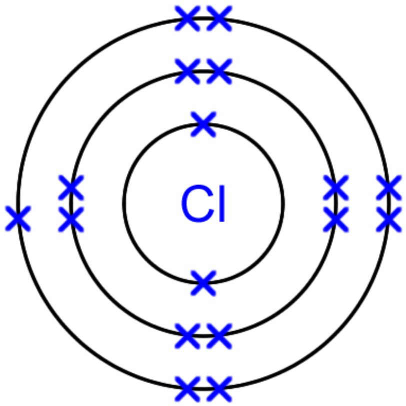
Chemical Bonding

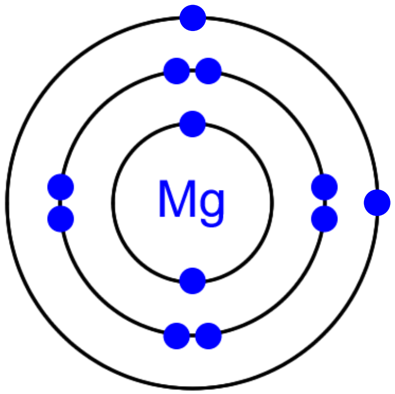
Ionic Bonding – A Note About Names



Chemical Bonding

Ionic Bonding – Magnesium Chloride

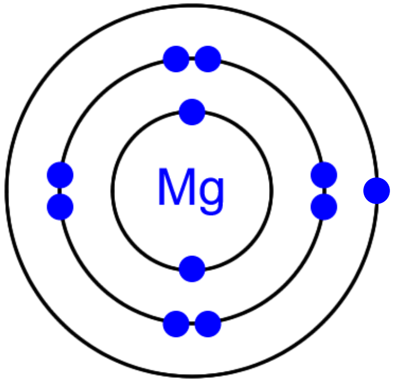


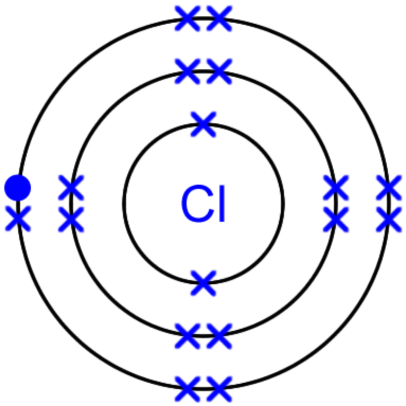


● = Electron of magnesium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Magnesium Chloride

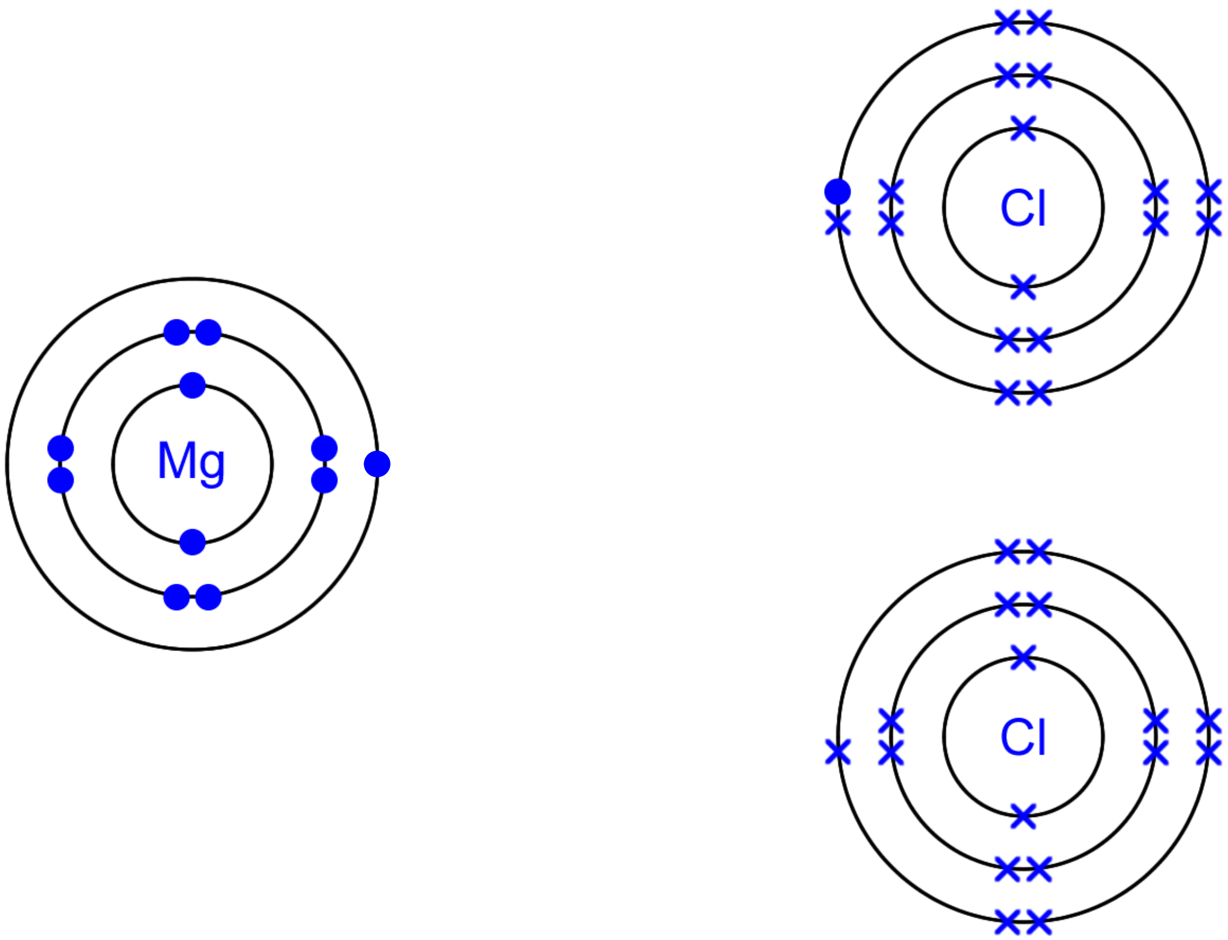




• = Electron of magnesium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Magnesium Chloride



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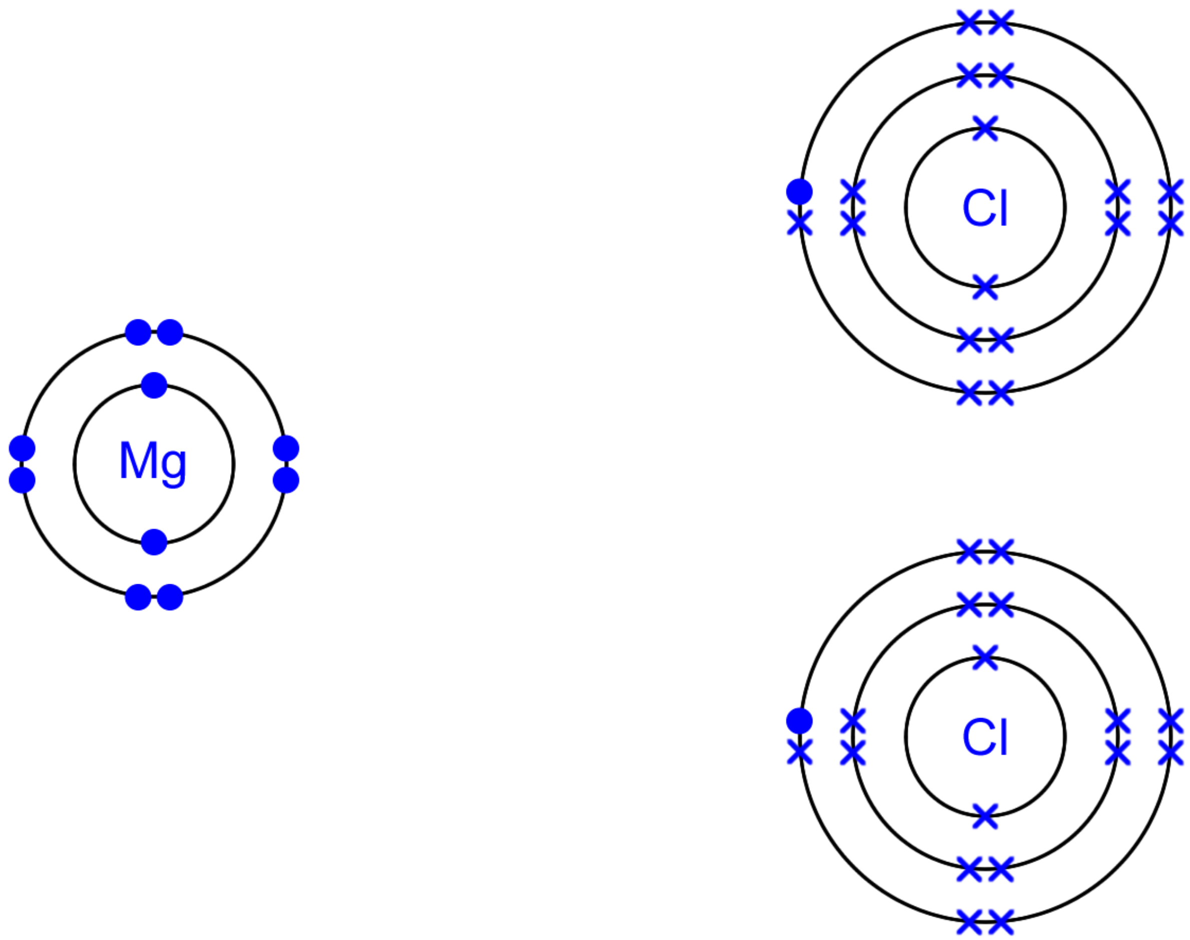
Chemical Bonding

Ionic Bonding – Magnesium Chloride



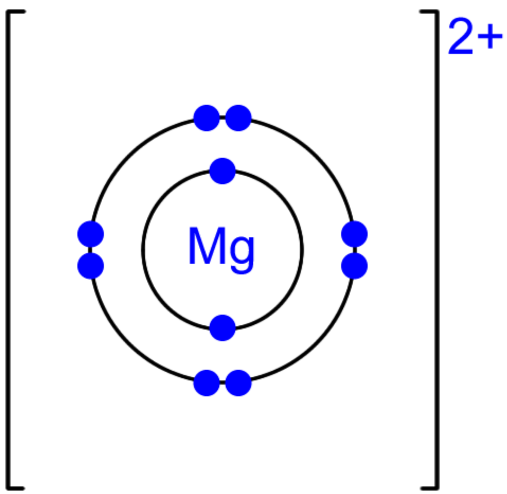
• = Electron of magnesium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Magnesium Chloride – $MgCl_2$

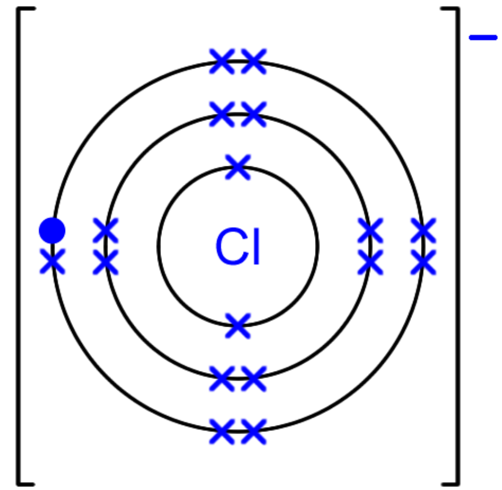
Positive Magnesium Ion (Cation)

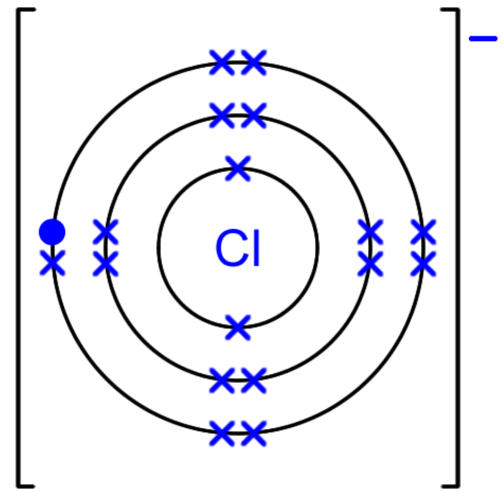
- Number of Protons = 12
- Number of Electrons = 10
- Overall Charge = (+12) + (-10) = +2



Negative Chloride Ion (Anion)

- Number of Protons = 17
- Number of Electrons = 18
- Overall Charge = (+17) + (-18) = -1

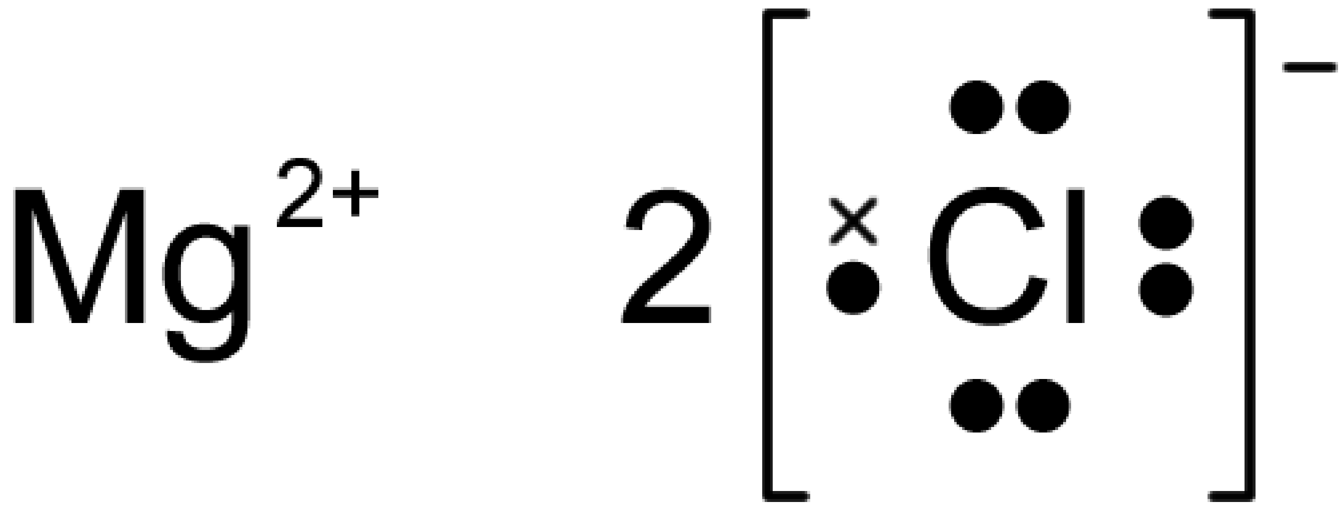




• = Electron of magnesium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Magnesium Chloride – $MgCl_2$

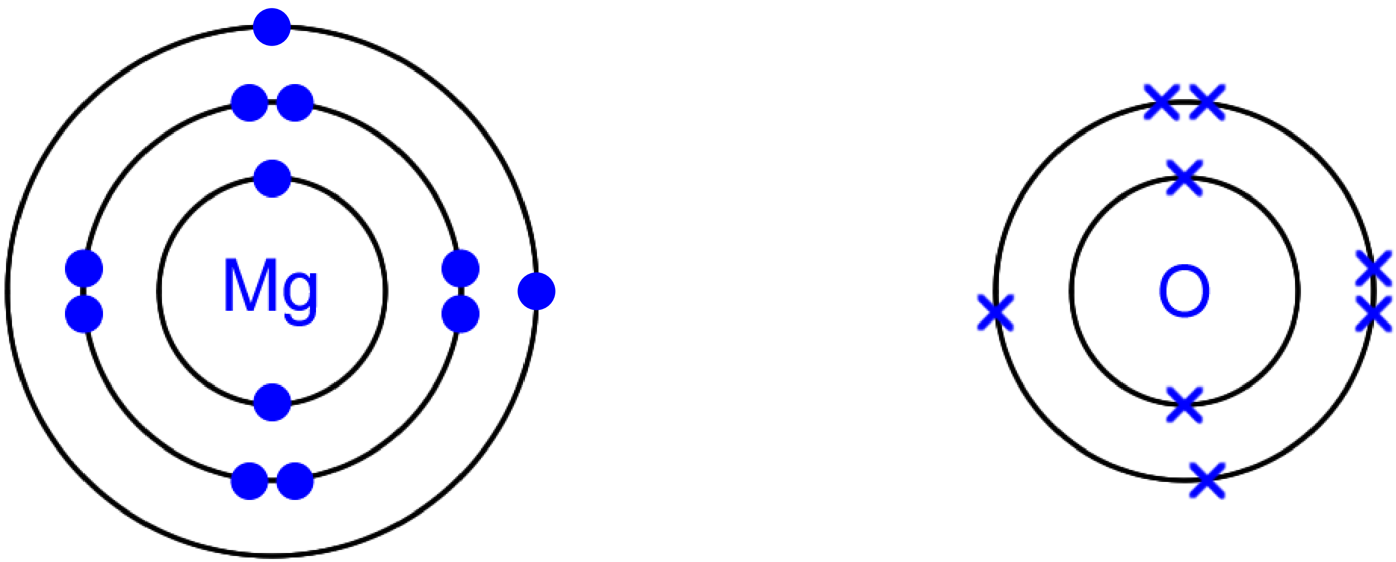


- The dot-and-cross diagram for magnesium chloride that should be used as an answer in an examination.

• = Electron of chlorine. × = Electron of magnesium.

Chemical Bonding

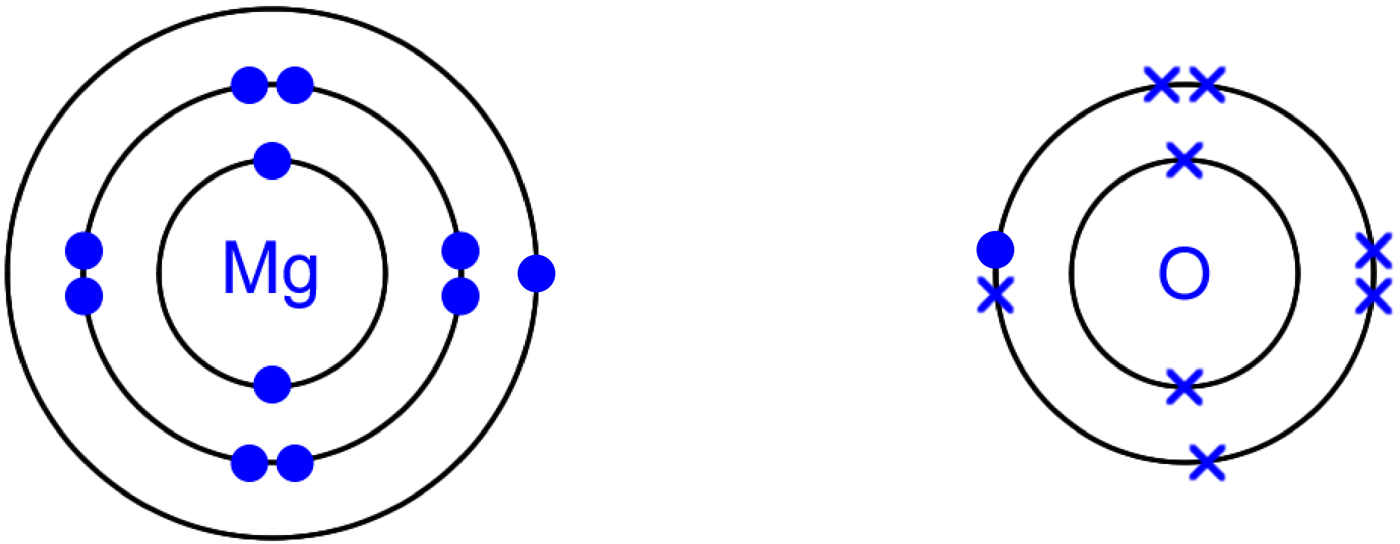
Ionic Bonding – Magnesium Oxide



● = Electron of magnesium. × = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Magnesium Oxide



• = Electron of magnesium. × = Electron of oxygen.

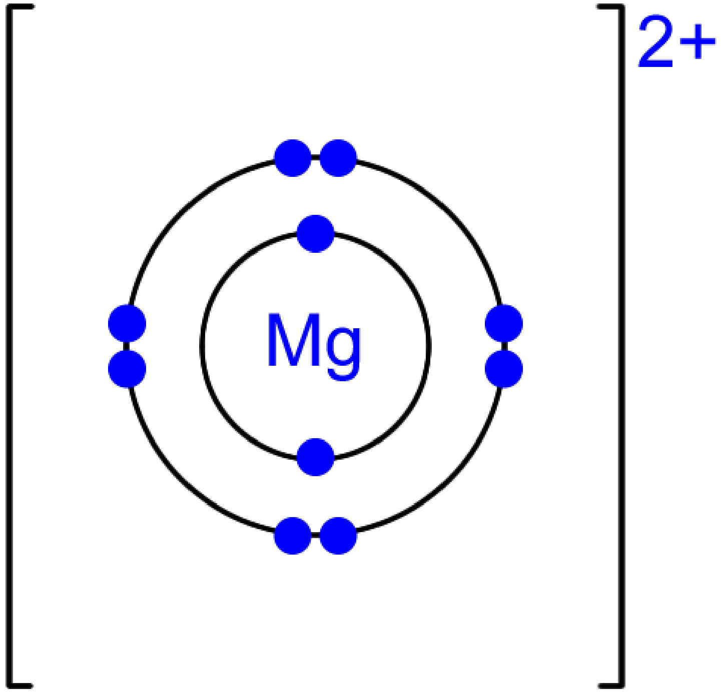
Chemical Bonding

Ionic Bonding – Magnesium Oxide

• = Electron of magnesium. × = Electron of oxygen.

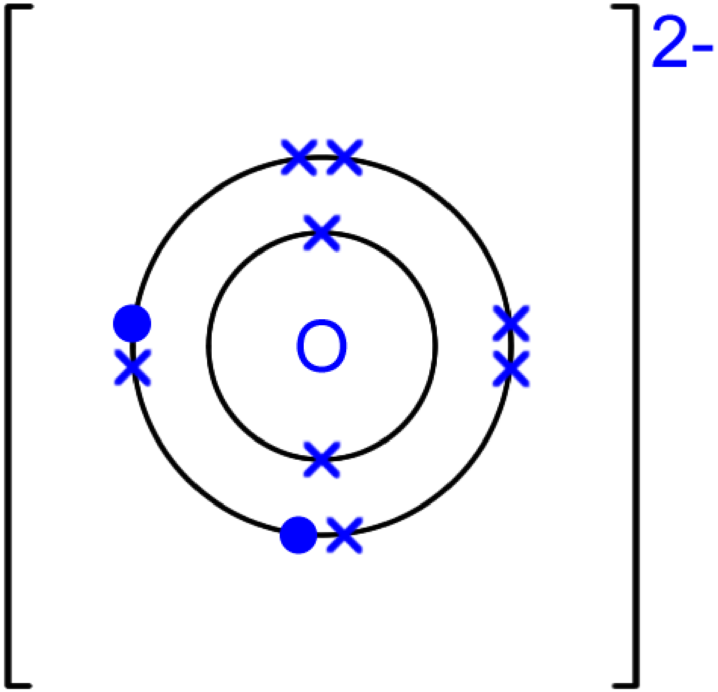
Chemical Bonding

Ionic Bonding – Magnesium Oxide – MgO



Positive Magnesium Ion (Cation)

- Number of Protons = 12
- Number of Electrons = 10
- Overall Charge = (+12) + (-10) = +2



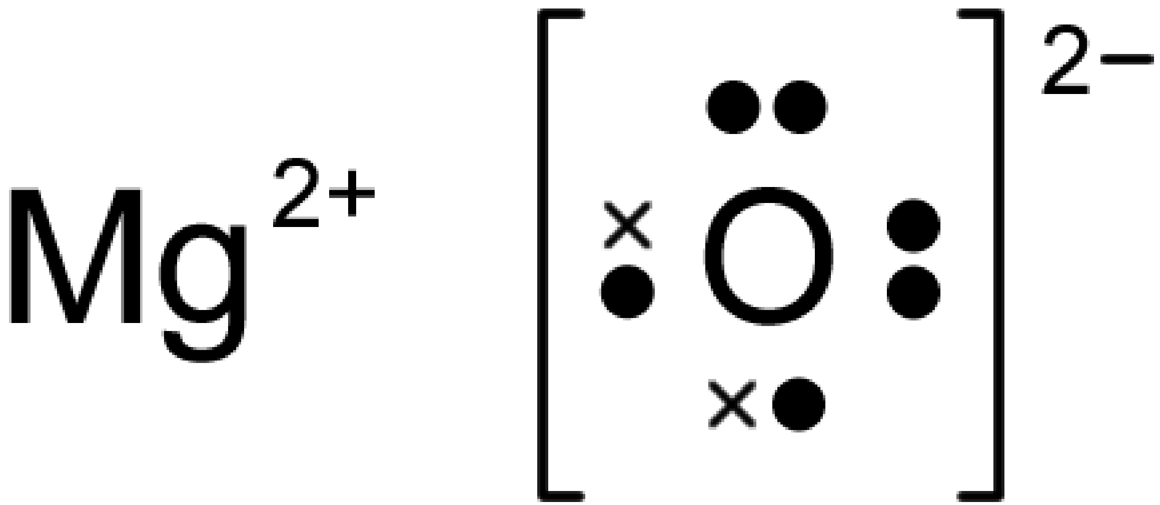
Negative Oxide Ion (Anion)

- Number of Protons = 8
- Number of Electrons = 10
- Overall Charge = (+8) + (-10) = -2

• = Electron of magnesium. × = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Magnesium Oxide – MgO

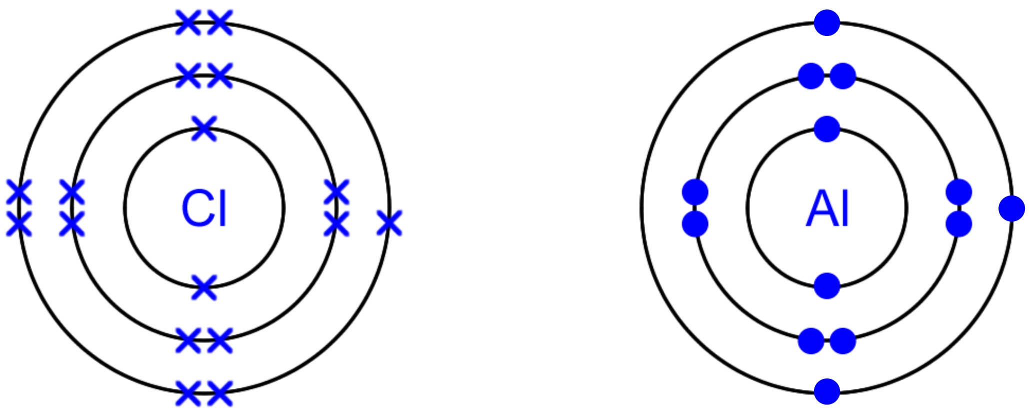


- The dot-and-cross diagram for magnesium oxide that should be used as an answer in an examination.

• = Electron of oxygen. × = Electron of magnesium.

Chemical Bonding

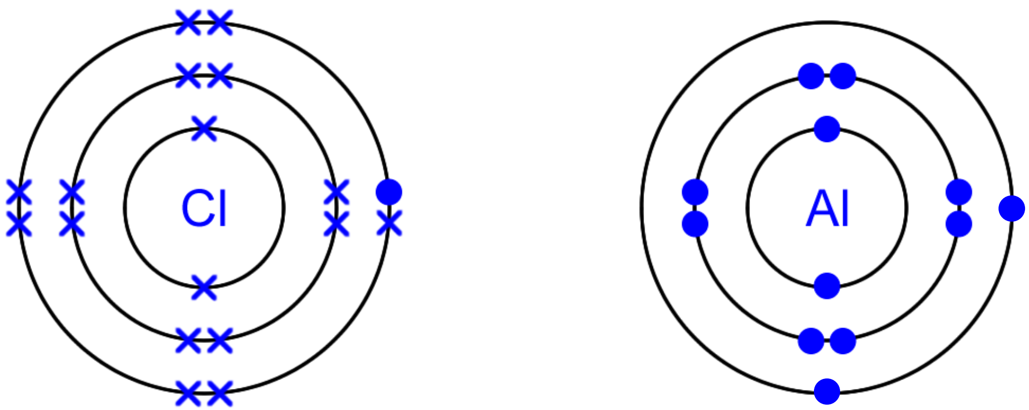
Ionic Bonding – Aluminium Chloride



• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

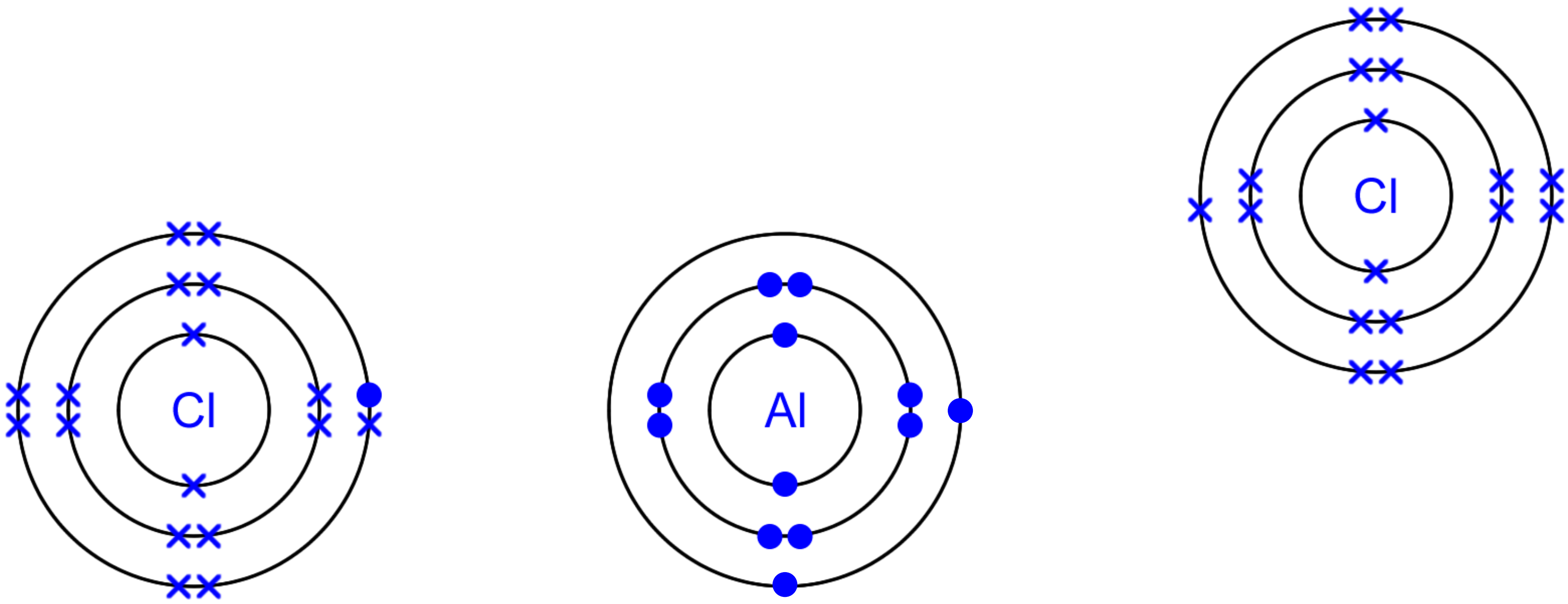
Ionic Bonding – Aluminium Chloride



• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

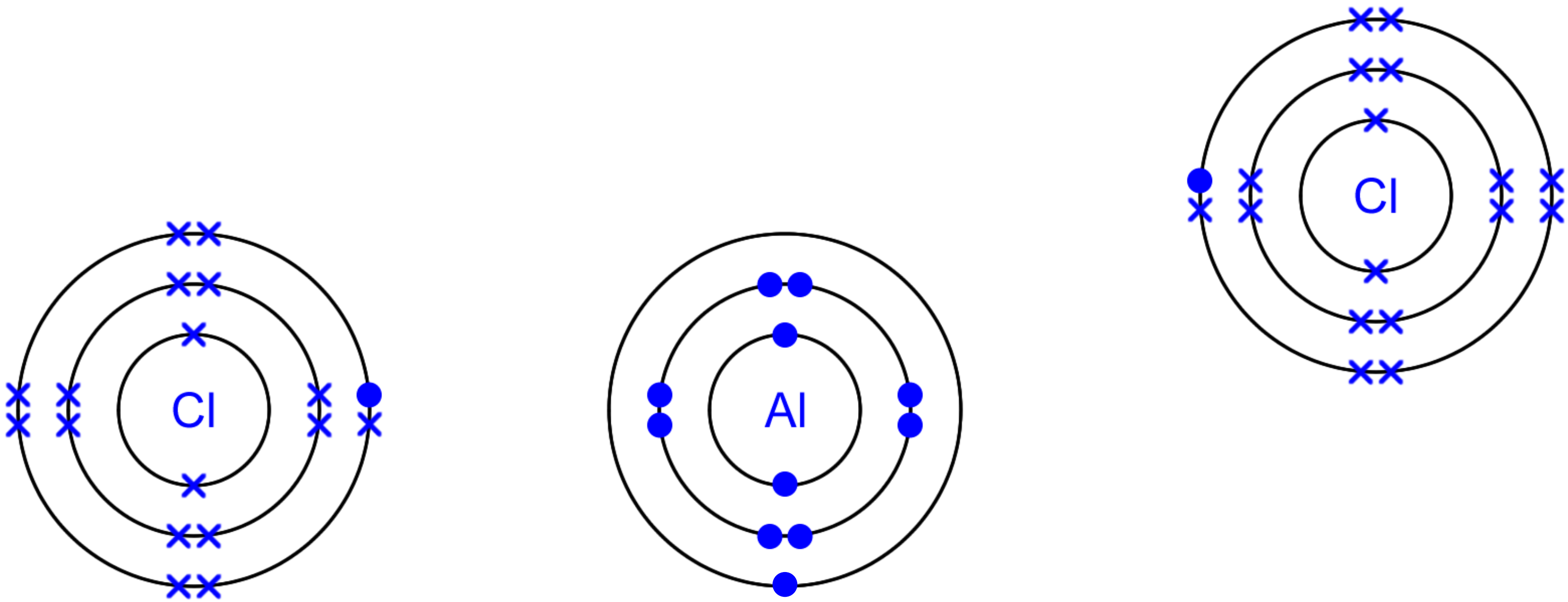
Ionic Bonding – Aluminium Chloride



• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

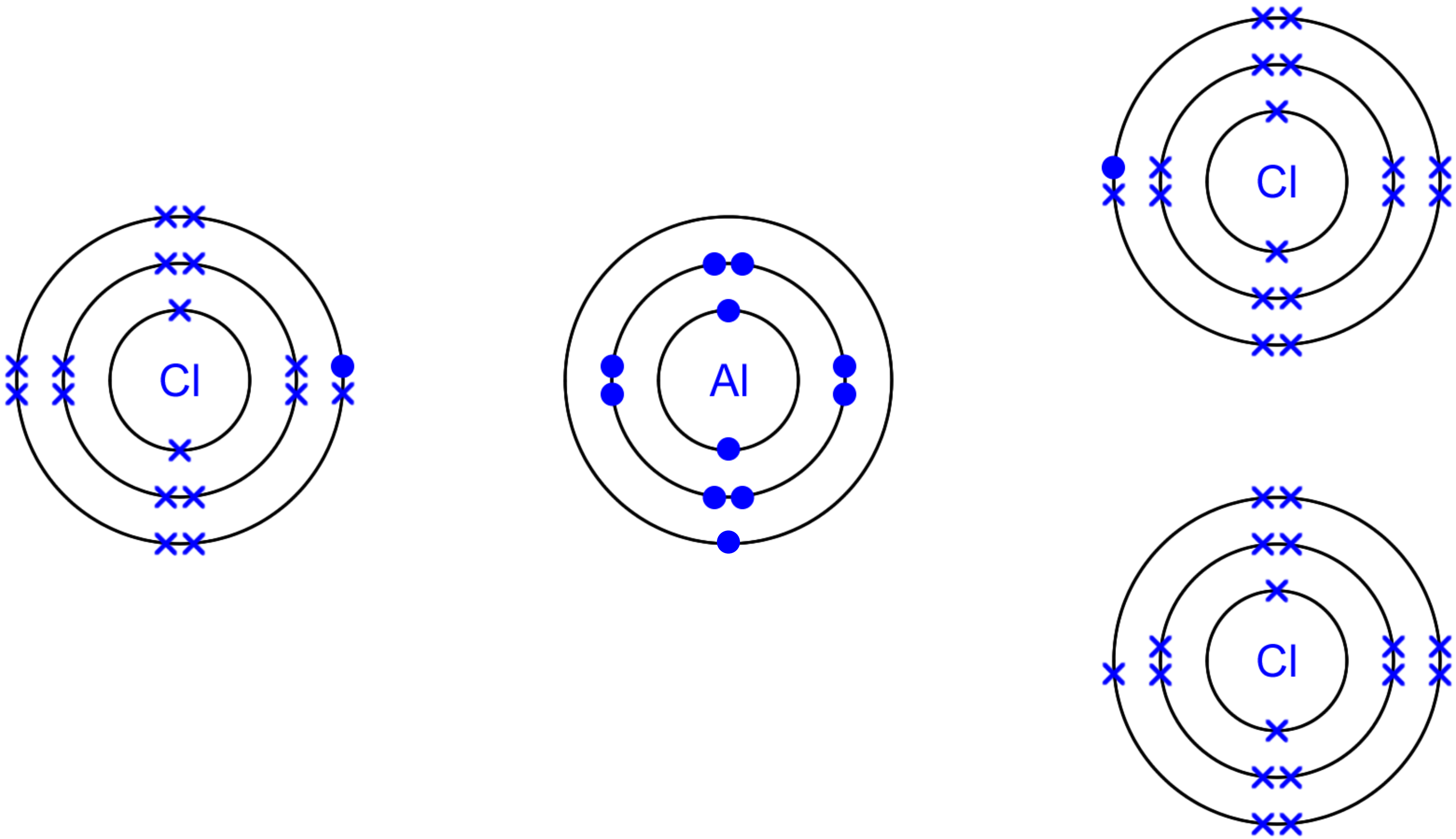
Ionic Bonding – Aluminium Chloride



• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

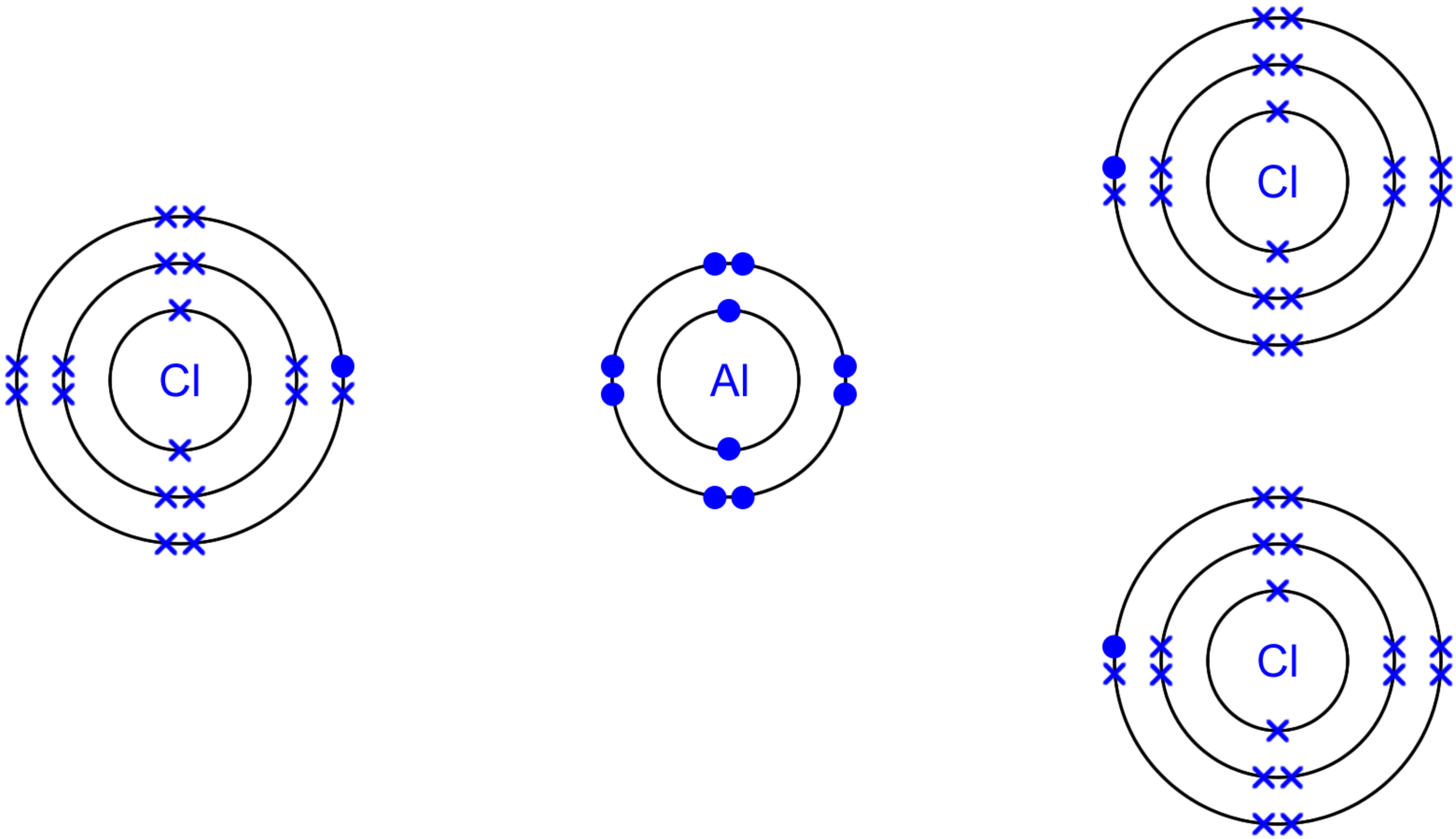
Ionic Bonding – Aluminium Chloride



• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Aluminium Chloride



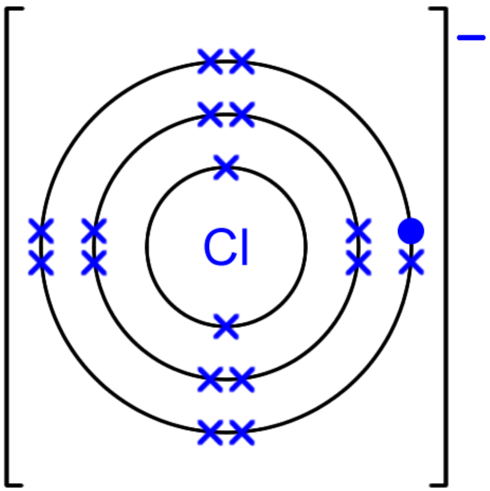
• = Electron of aluminium.   × = Electron of chlorine.

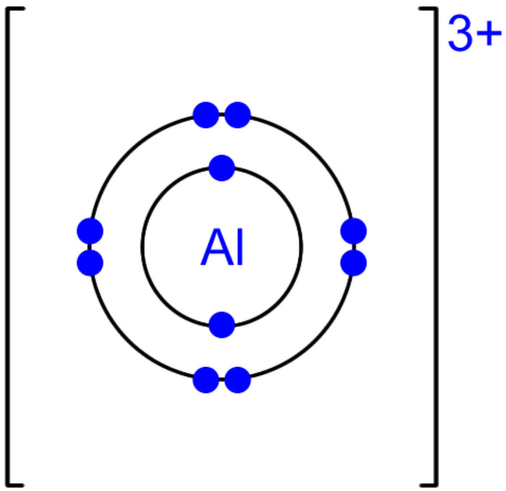
Chemical Bonding

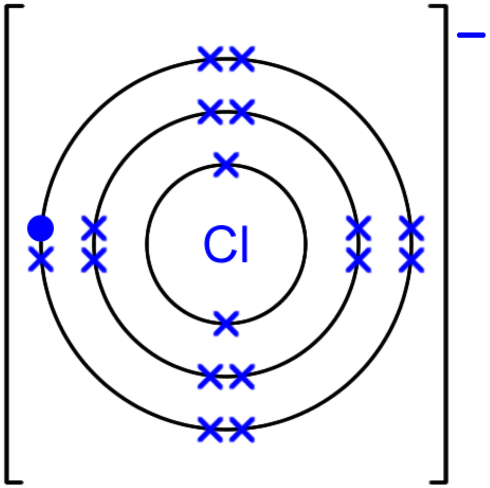
Ionic Bonding – Aluminium Chloride – $AlCl_3$

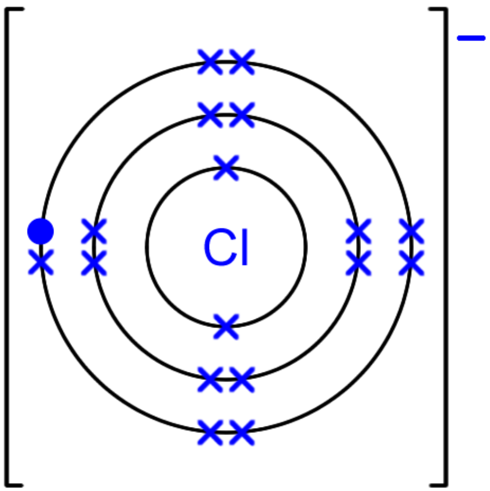
Positive Aluminium Ion (Cation)

- Number of Protons = 13
- Number of Electrons = 10
- Overall Charge = (+13) + (-10) = +3









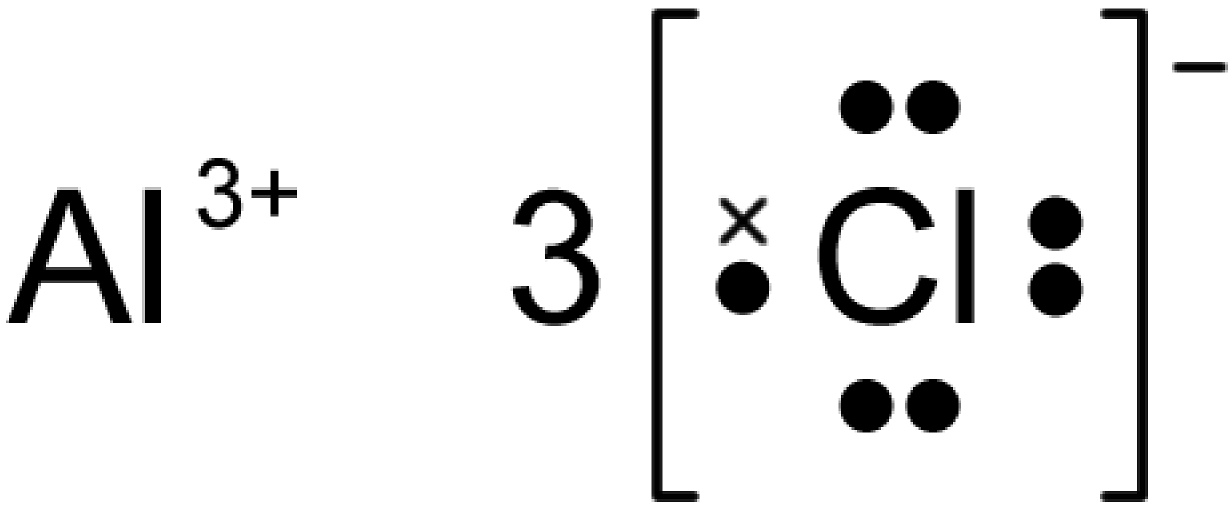
Negative Chloride Ion (Anion)

- Number of Protons = 17
- Number of Electrons = 18
- Overall Charge = (+17) + (-18) = -1

• = Electron of aluminium. × = Electron of chlorine.

Chemical Bonding

Ionic Bonding – Aluminium Chloride – $AlCl_3$

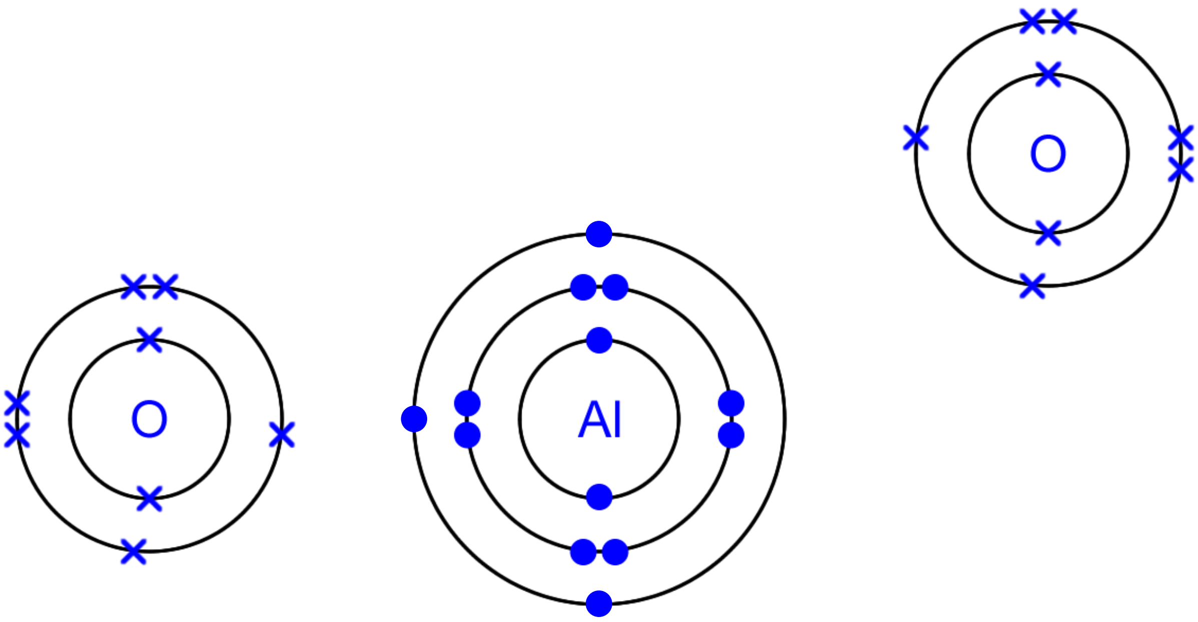


- The dot-and-cross diagram for aluminium chloride that should be used as an answer in an examination.

• = Electron of chlorine. × = Electron of aluminium.

Chemical Bonding

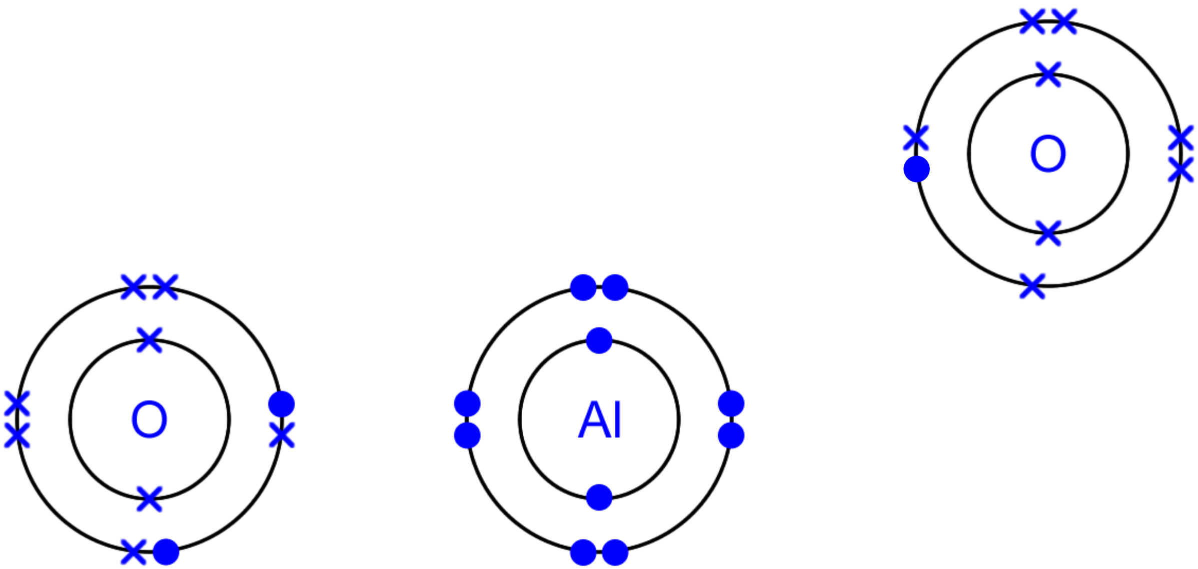
Ionic Bonding – Aluminium Oxide



● = Electron of aluminium.   × = Electron of oxygen.

Chemical Bonding

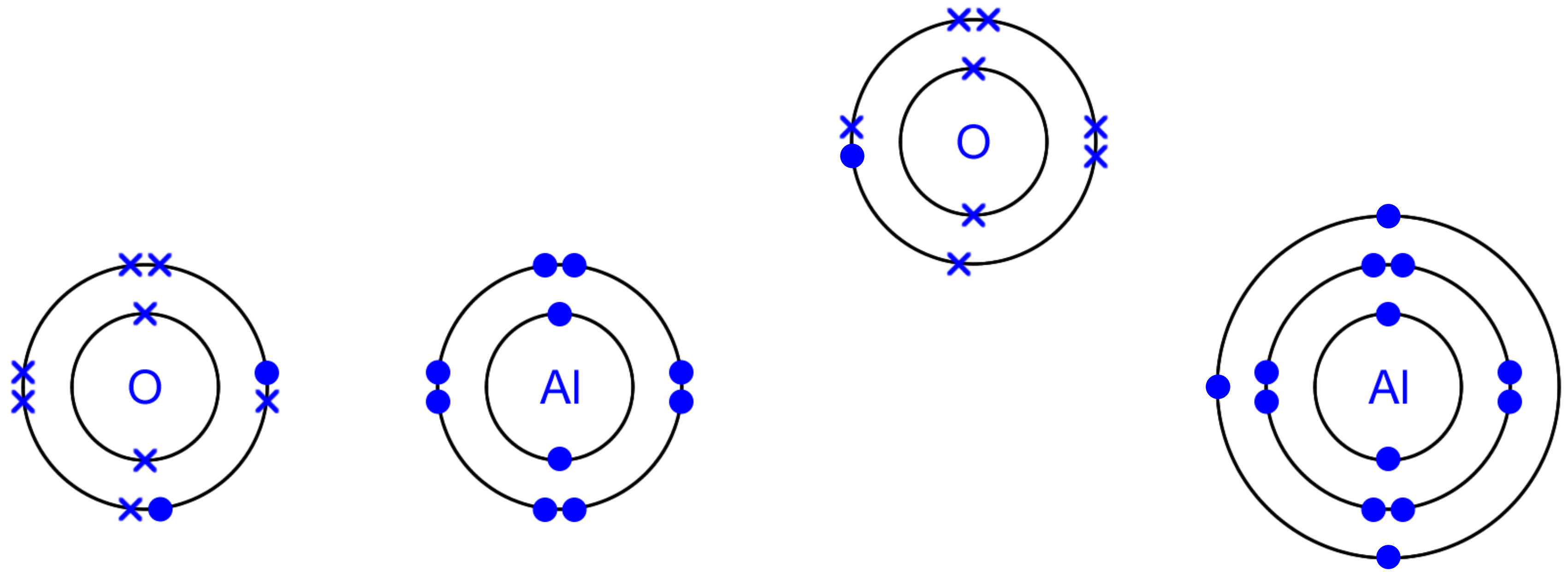
Ionic Bonding – Aluminium Oxide



• = Electron of aluminium. × = Electron of oxygen.

Chemical Bonding

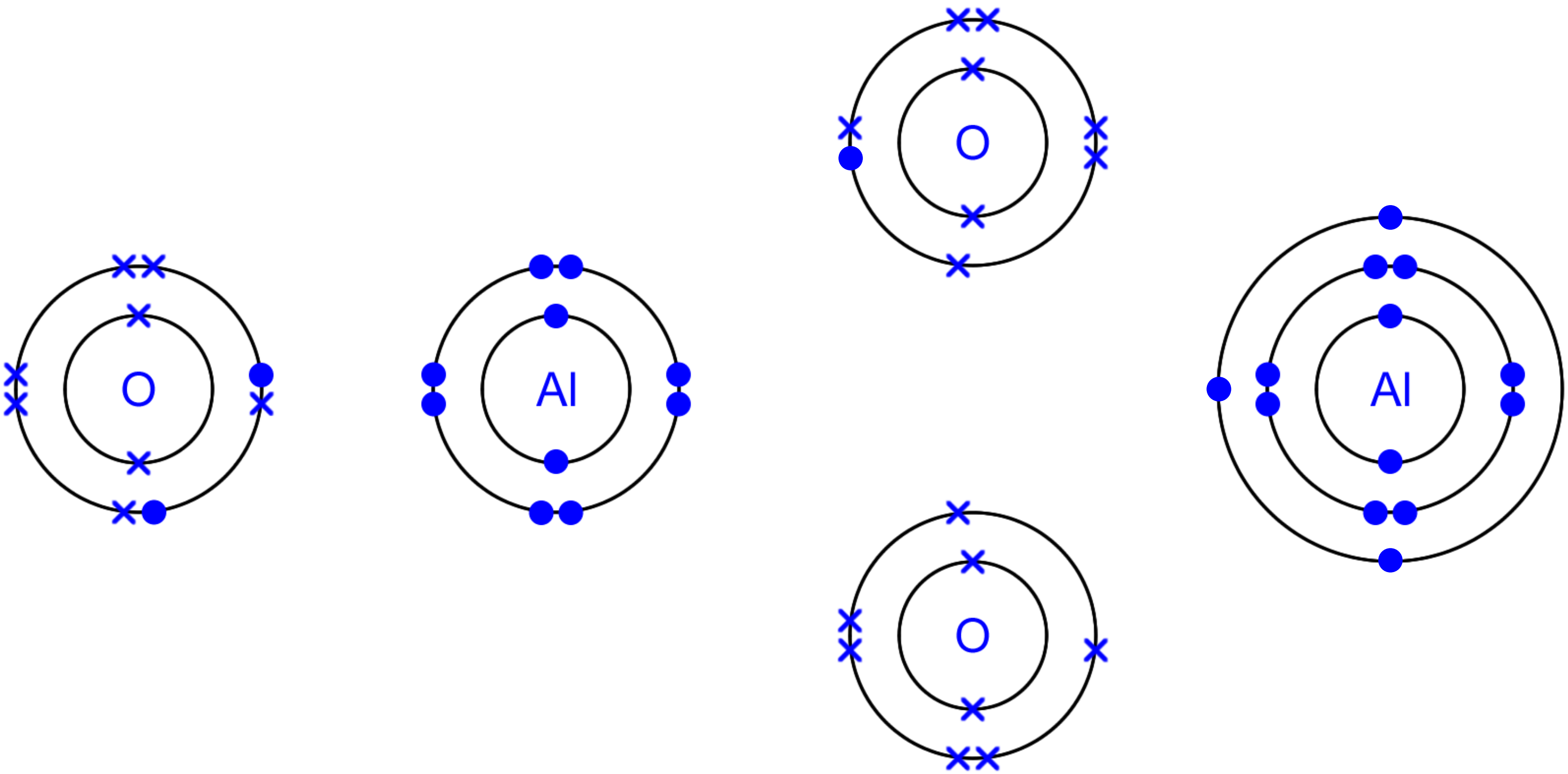
Ionic Bonding – Aluminium Oxide



● = Electron of aluminium. × = Electron of oxygen.

Chemical Bonding

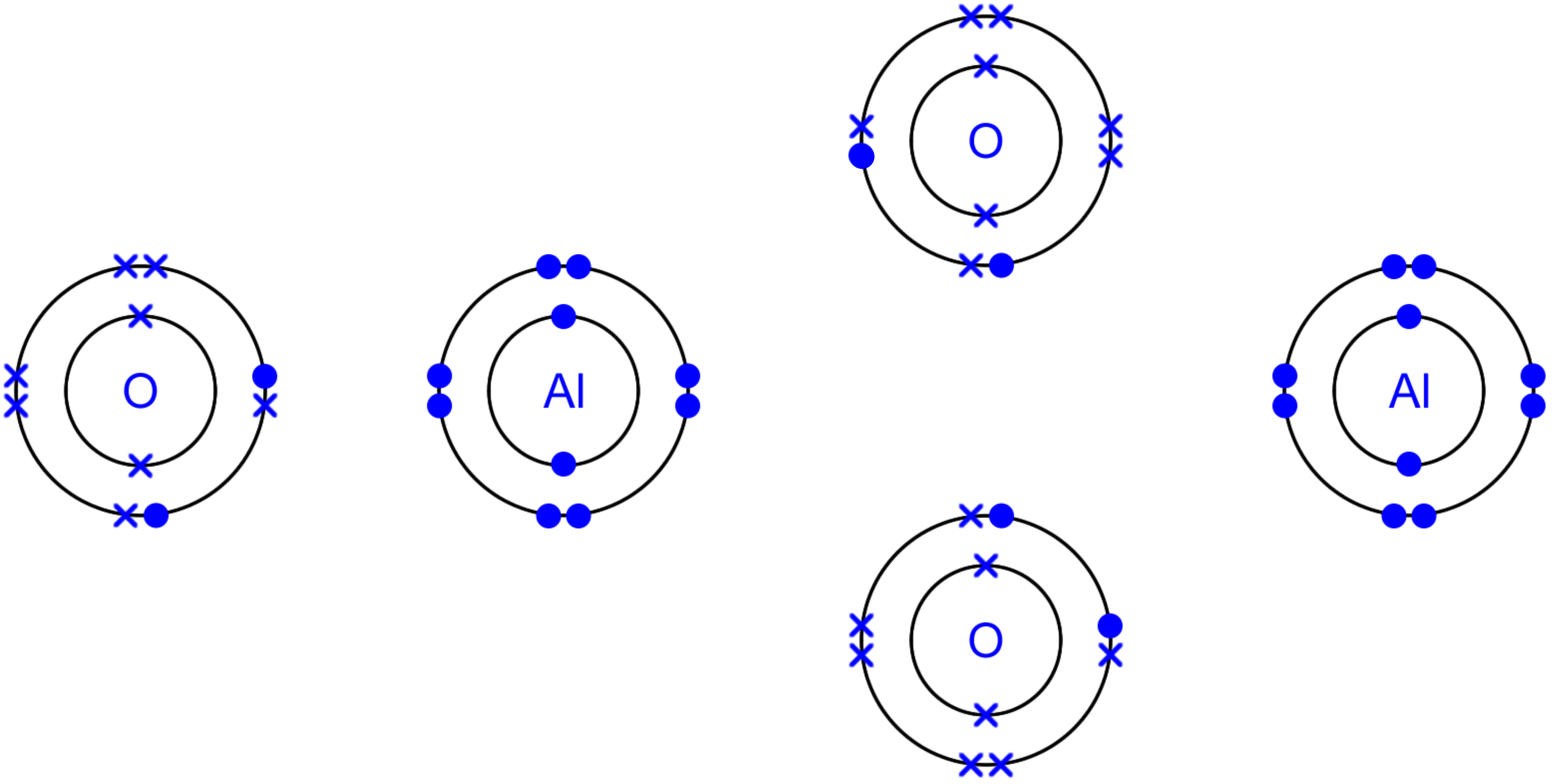
Ionic Bonding – Aluminium Oxide



• = Electron of aluminium. × = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Aluminium Oxide



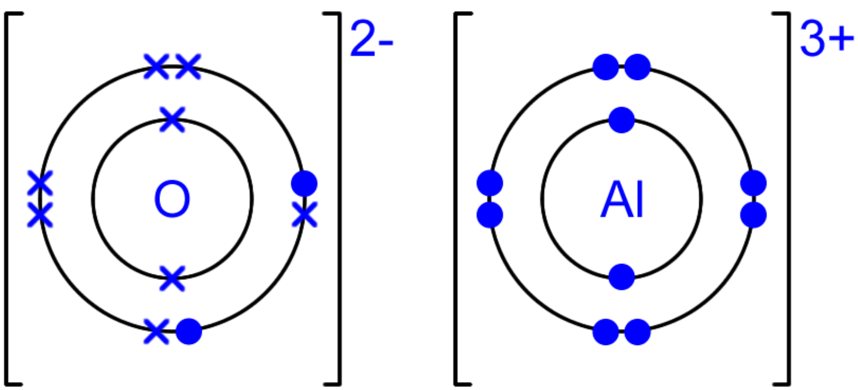
• = Electron of aluminium. × = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Aluminium Oxide – Al_2O_3

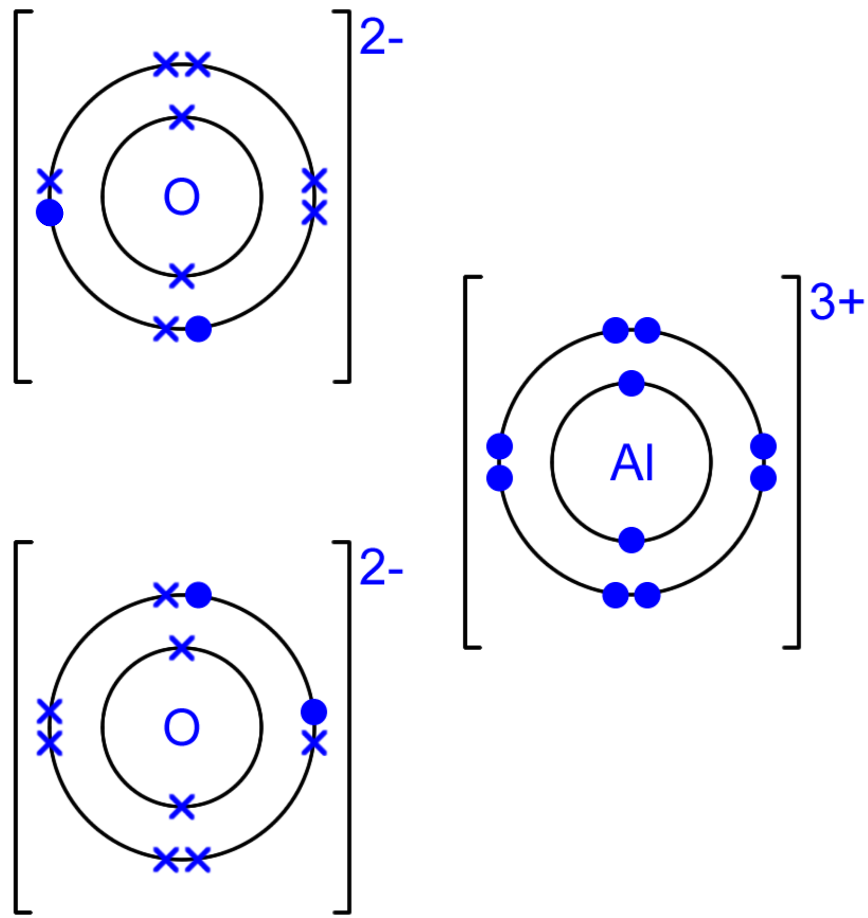
Positive Aluminium Ion (Cation)

- Number of Protons = 13
- Number of Electrons = 10
- Overall Charge = (+13) + (-10) = +3



Negative Oxide Ion (Anion)

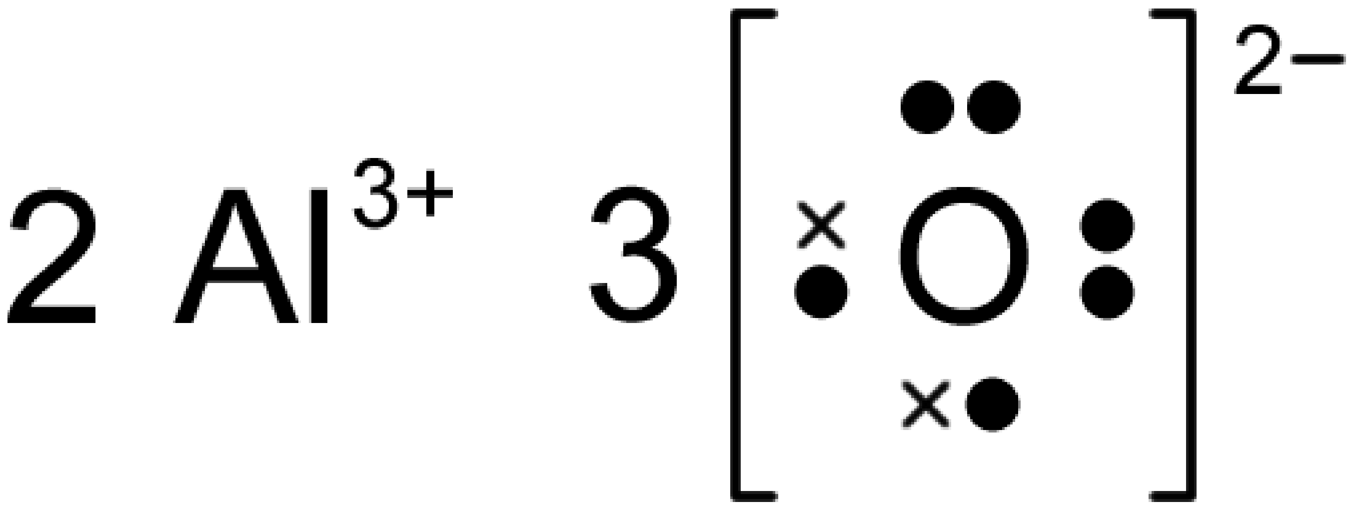
- Number of Protons = 8
- Number of Electrons = 10
- Overall Charge = (+8) + (-10) = -2



• = Electron of aluminium. × = Electron of oxygen.

Chemical Bonding

Ionic Bonding – Aluminium Oxide – Al_2O_3



- The dot-and-cross diagram for aluminium oxide that should be used as an answer in an examination.

• = Electron of oxygen. × = Electron of aluminium.

Chemical Bonding

3. Can I derive the *formula* of a compound based upon where the chemical elements are positioned in the Periodic Table?

Chemical Bonding

Group	1	2	13	14	15	16	17
Number of Valence Electrons							
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration							
Valency of Element							

Chemical Bonding

Group	1	2	13	14	15	16	17
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration							
Valency of Element							

Chemical Bonding

Group	**1**	**2**	**13**	**14**	**15**	**16**	**17**
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element							

Chemical Bonding

Group	**1**	**2**	**13**	**14**	**15**	**16**	**17**
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element	1	2	3	4	3	2	1

Chemical Bonding

Group	1	2	13	14	15	16	17
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element	1	2	3	4	3	2	1

- The formula of a compound can be easily derived by *swapping* the *valencies* of the two elements.

e.g. potassium (Group 1) and oxygen (Group 16)

Chemical Bonding

Group	**1**	**2**	**13**	**14**	**15**	**16**	**17**
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element	1	2	3	4	3	2	1

- The formula of a compound can be easily derived by *swapping* the *valencies* of the two elements.

e.g. potassium (Group 1) and oxygen (Group 16)

1 2

K O

…becomes…

K_2O

Chemical Bonding

Group	1	2	13	14	15	16	17
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element	1	2	3	4	3	2	1

- The formula of a compound can be easily derived by *swapping* the *valencies* of the two elements.

e.g. calcium (Group 2) and nitrogen (Group 15)

Chemical Bonding

Group	1	2	13	14	15	16	17
Number of Valence Electrons	1	2	3	4	5	6	7
Number of Electrons Lost or Gained to Obtain Noble Gas Electronic Configuration	1	2	3	4	3	2	1
Valency of Element	1	2	3	4	3	2	1

- The formula of a compound can be easily derived by *swapping* the *valencies* of the two elements.

e.g. calcium (Group 2) and nitrogen (Group 15)

2 3

Ca N

…becomes…

Ca_3N_2

Chemical Bonding

Ionic Bonding

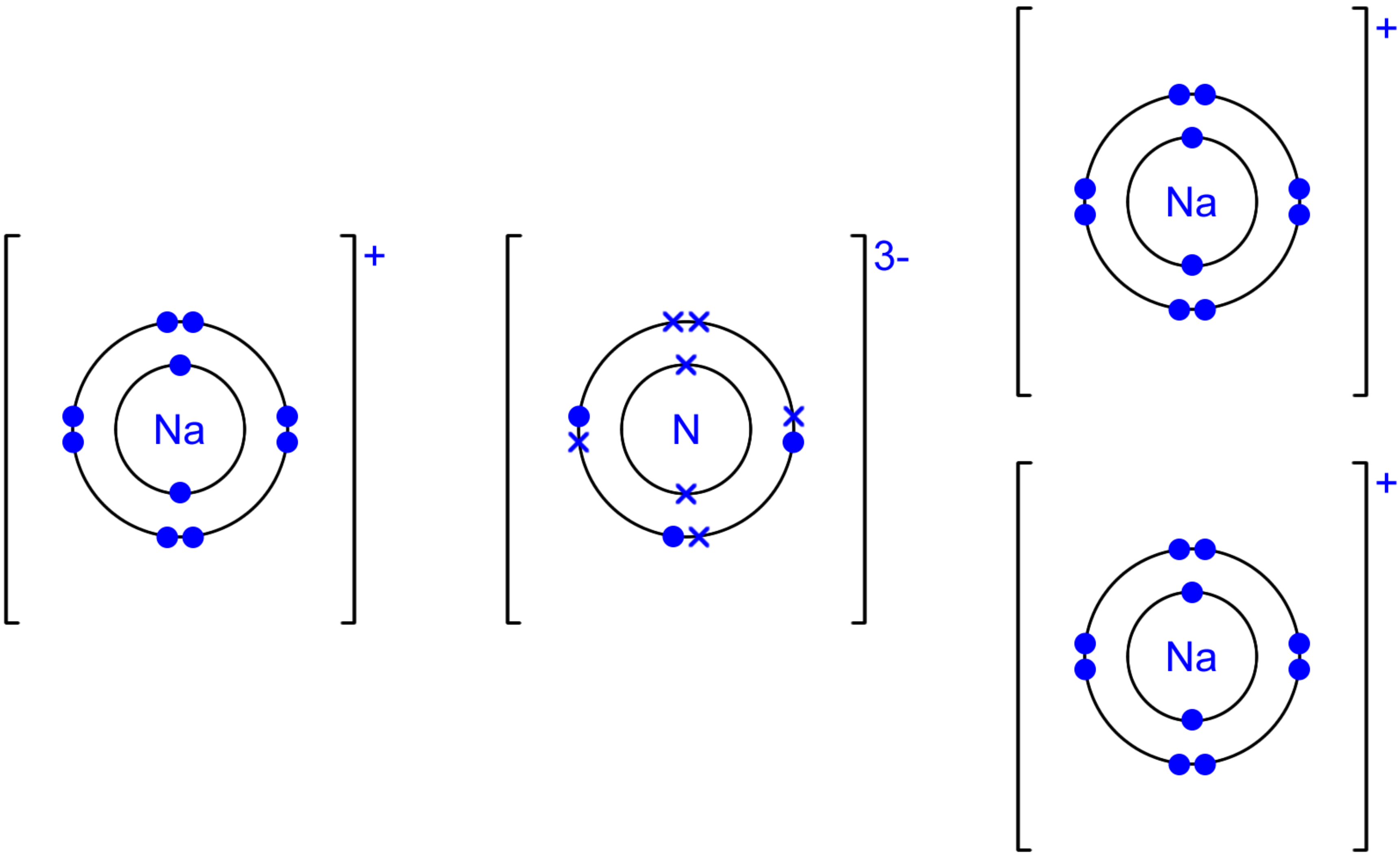
4. Self-assessment

- Draw dot-and-cross diagrams to show the bonding in:

a) Sodium nitride.
b) Magnesium nitride.
c) Aluminium nitride.

Chemical Bonding

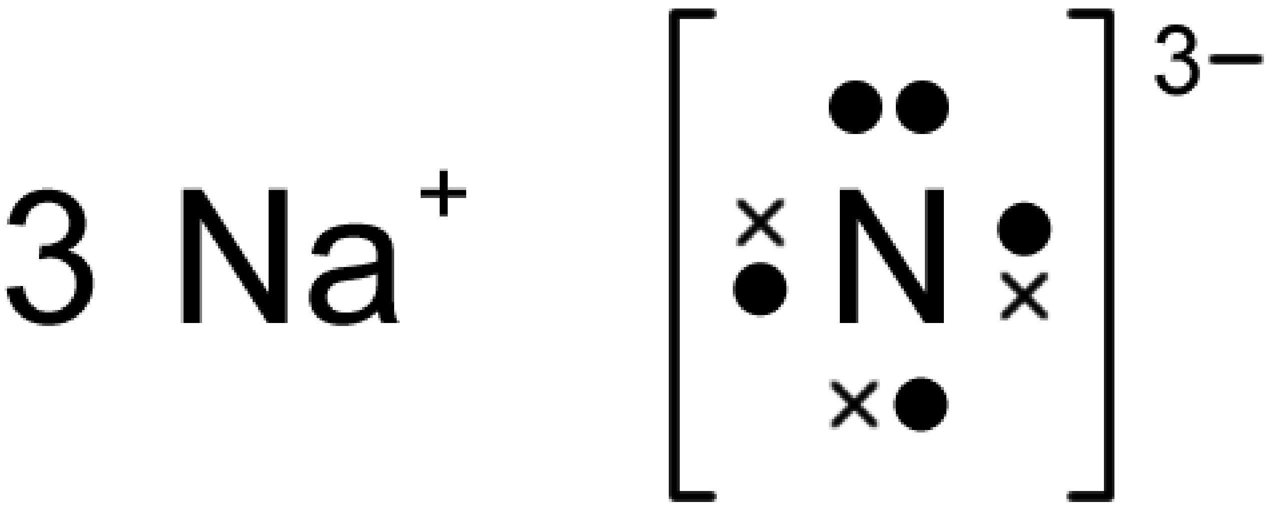
Ionic Bonding – Sodium Nitride – Na_3N



• = Electron of sodium. × = Electron of nitrogen.

Chemical Bonding

Ionic Bonding – Sodium Nitride – Na_3N

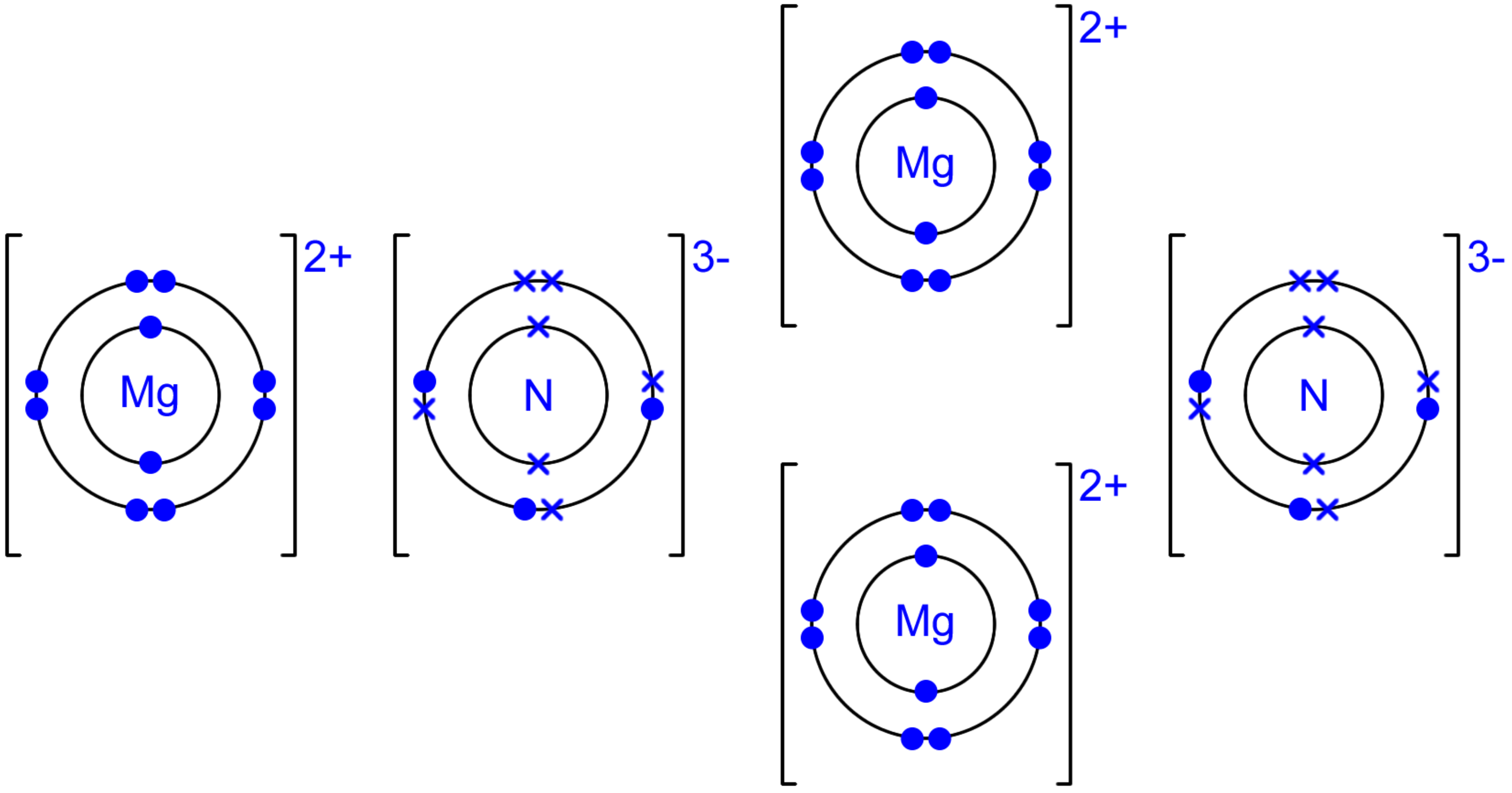


- The dot-and-cross diagram for sodium nitride that should be used as an answer in an examination.

• = Electron of nitrogen. × = Electron of sodium.

Chemical Bonding

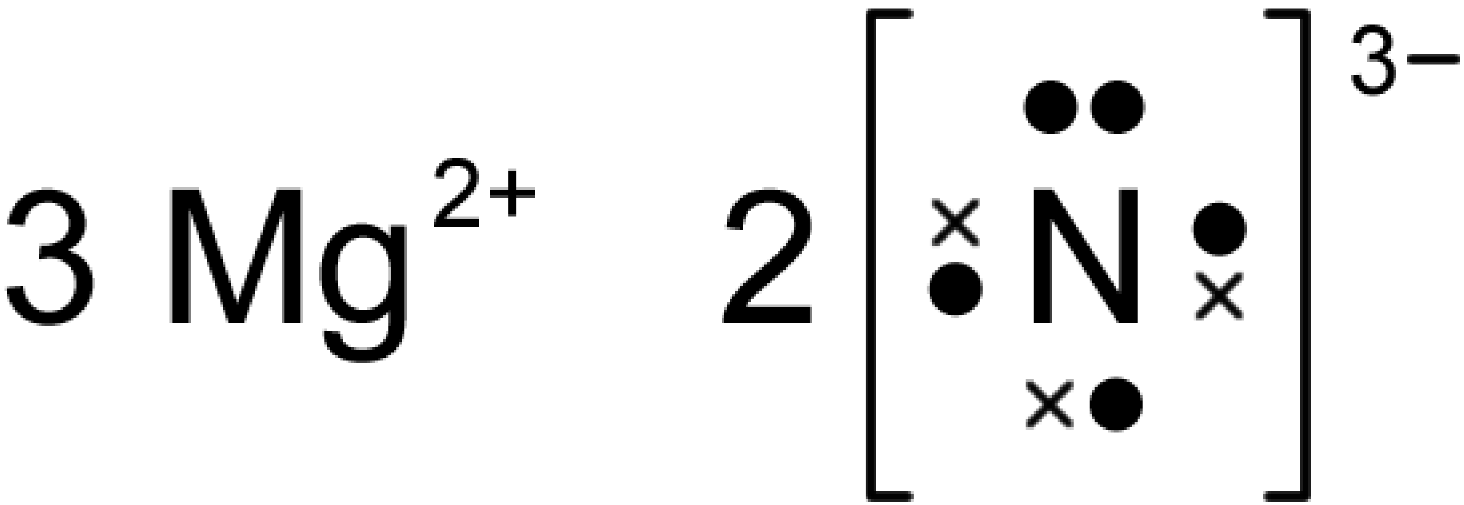
Ionic Bonding – Magnesium Nitride – Mg_3N_2



• = Electron of magnesium. × = Electron of nitrogen.

Chemical Bonding

Ionic Bonding – Magnesium Nitride – Mg_3N_2

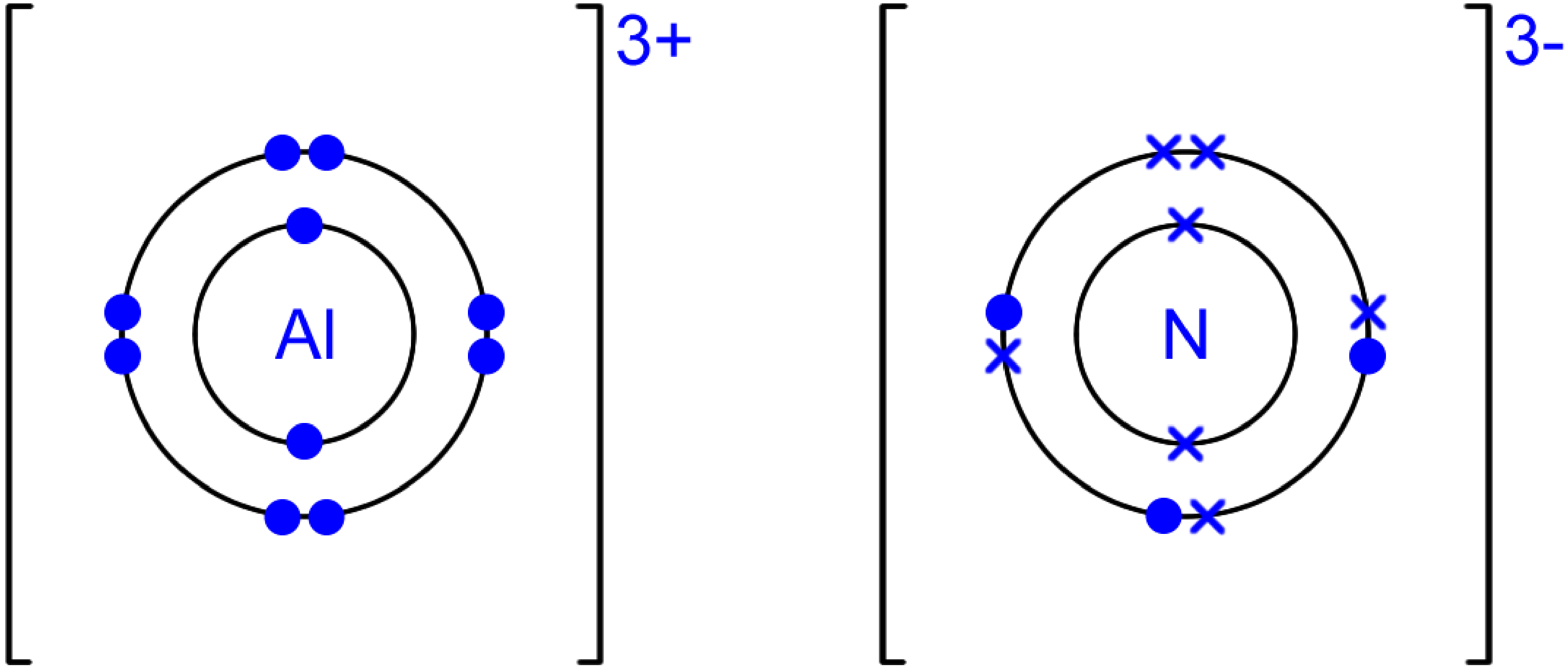


- The dot-and-cross diagram for magnesium nitride that should be used as an answer in an examination.

• = Electron of nitrogen. × = Electron of magnesium.

Chemical Bonding

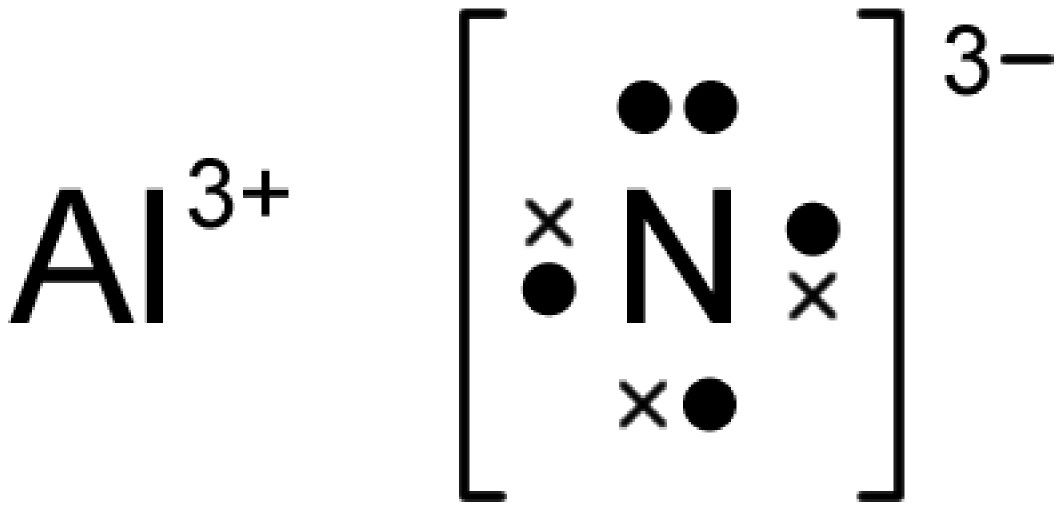
Ionic Bonding – Aluminium Nitride – A*l*N



• = Electron of aluminium. × = Electron of nitrogen.

Chemical Bonding

Ionic Bonding – Aluminium Nitride – A*l*N



- The dot-and-cross diagram for aluminium nitride that should be used as an answer in an examination.

• = Electron of nitrogen. × = Electron of aluminium.

Chemical Bonding

Ionic Bonding – Summary

- Ionic bonding occurs between a *metallic element* and a *non-metallic element*.
- The metal *transfers* its valence electron(s) into the valence shell of the non-metal.
- Both the metal and the non-metal obtain *noble gas electronic configurations*.
- Due to the loss of negatively charged electrons, the metal atom transforms into a *positive ion* (cation).
- Due to the gain of negatively charged electrons, the non-metal atom transforms into a *negative ion* (anion).
- Oppositely charged ions attract towards each other and arrange themselves in a 3D *crystal lattice*.

Chemical Bonding

Ionic Bonding – Properties – Summary

- Ionic compounds have *high melting points* and *boiling points* due to the strong electrostatic force of attraction that holds the positive and negative ions together.

- Ionic compounds are *hard but brittle*. When ions with a similar charge are forced together they repel, and the ionic crystal shatters.

- Ionic compounds are *soluble in polar solvents* such as water, but are *insoluble in non-polar solvents* such as oil and hexane.

- Ionic compounds are *electrolytes*. They do *not* conduct electricity when in the *solid state*, but *do* conduct electricity when either *molten* or *dissolved in water*.

Online Search

- Identify an ionic compound that is present in *toothpaste*. How is its function related to its structure and bonding?

- What ionic compound is *bone* composed of? How are its properties related to its structure and bonding?

- What ionic compound are the shells of *molluscs* composed of? How are its properties related to its structure and bonding?

Chemical Bonding

Covalent Bonding – Non-metals Only!

5. How do two or more atoms of *non-metallic chemical elements* react together to obtain noble gas electronic configurations?

Chemical Bonding

Covalent Bonding – Non-metals Only!

- Covalent bonding occurs when an atom of a *non-metallic* element bonds to another atom of a *non-metallic* element.

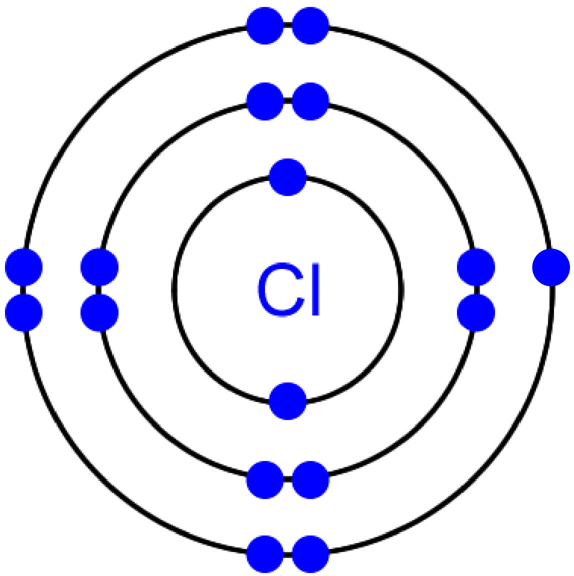
Group

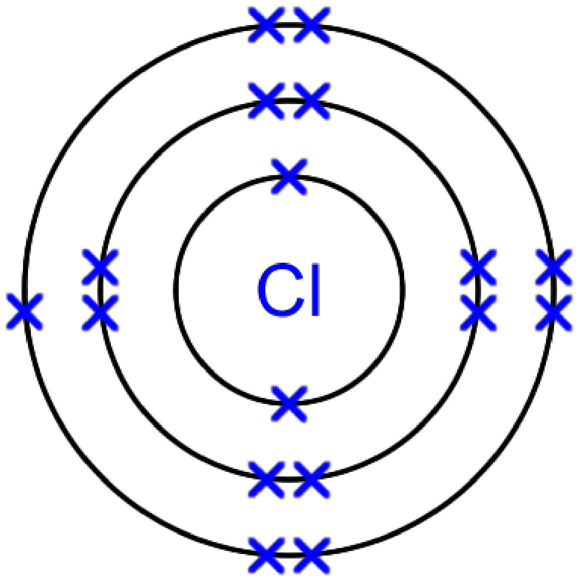
Period	1	2											13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

Key:
Blue = Metal
Yellow = Non-metal

Chemical Bonding

Covalent Bonding



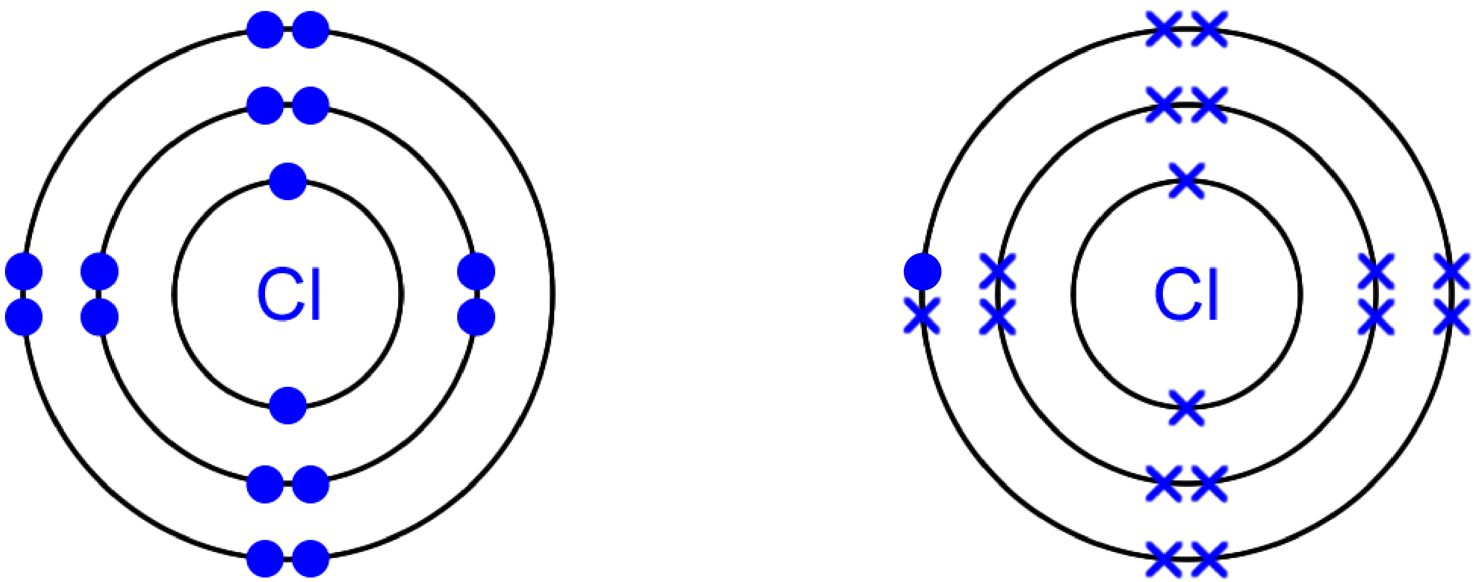


- Can two atoms of chlorine *both* obtain noble gas electronic configurations through *electron transfer*?

• = Electron of chlorine (left-hand-side). × = Electron of chlorine (right-hand-side).

Chemical Bonding

Covalent Bonding

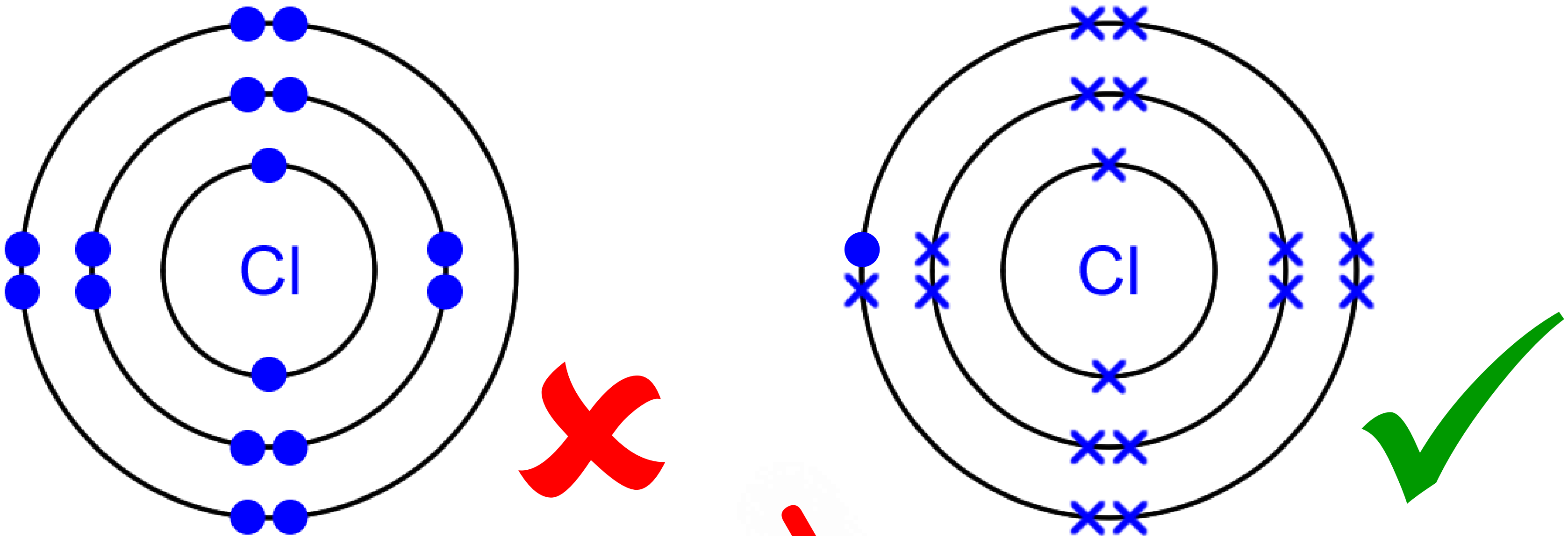


- Can two atoms of chlorine *both* obtain noble gas electronic configurations through *electron transfer*?

• = Electron of chlorine (left-hand-side).   × = Electron of chlorine (right-hand-side).

Chemical Bonding

Covalent Bonding



- Can two atoms of chlorine *both* obtain noble gas electronic configurations through *electron transfer*?

No!

● = Electron of chlorine (left-hand-side). × = Electron of chlorine (right-hand-side).

Chemical Bonding

Covalent Bonding – Fluorine

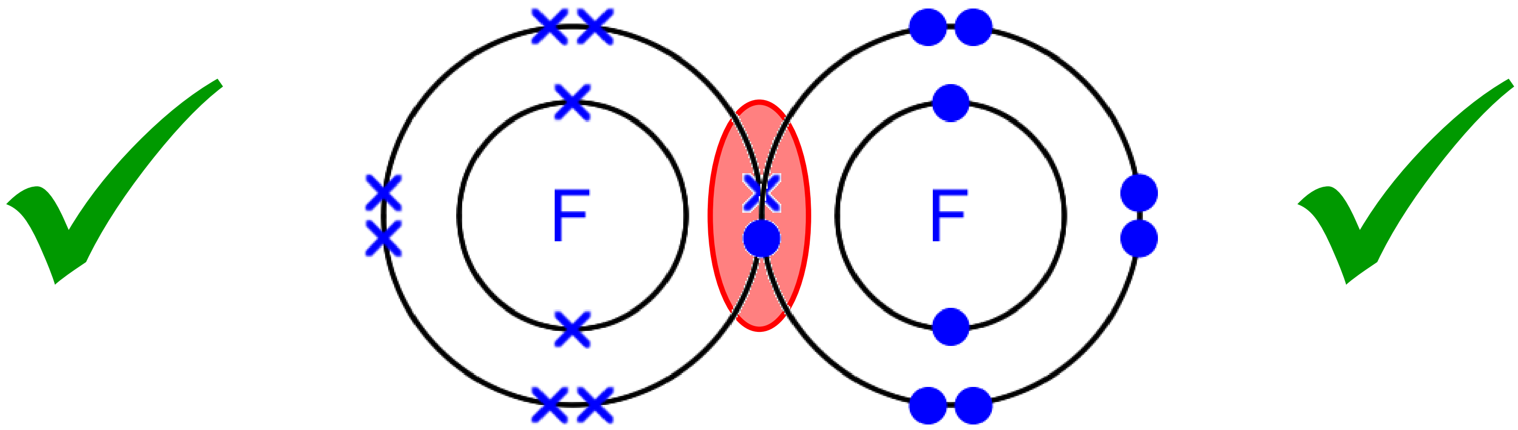
• In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of fluorine (right-hand-side). × = Electron of fluorine (left-hand-side).

Chemical Bonding

Covalent Bonding – Fluorine

Molecule of fluorine, formula: F_2



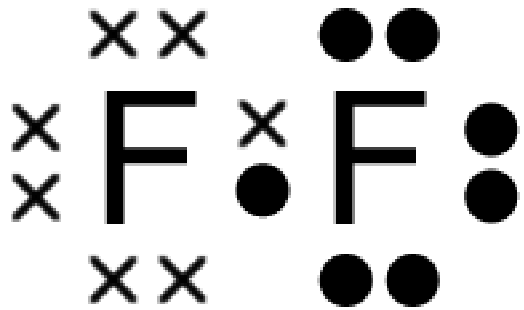
• In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of fluorine (right-hand-side). × = Electron of fluorine (left-hand-side).

Chemical Bonding

Covalent Bonding – Fluorine

Molecule of fluorine, formula: F_2



- The dot-and-cross diagram for molecular fluorine that should be used as an answer in an examination.

• = Electron of fluorine (right-hand-side). × = Electron of fluorine (left-hand-side).

Chemical Bonding

Covalent Bonding – Hydrogen

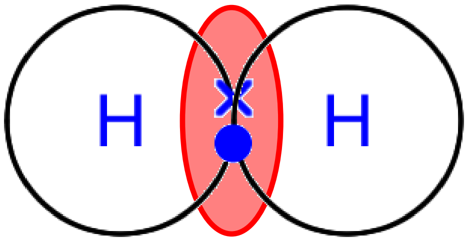
• In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of hydrogen (right-hand-side). × = Electron of hydrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Hydrogen

Molecule of hydrogen, formula: H_2



• In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of hydrogen (right-hand-side). × = Electron of hydrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Hydrogen

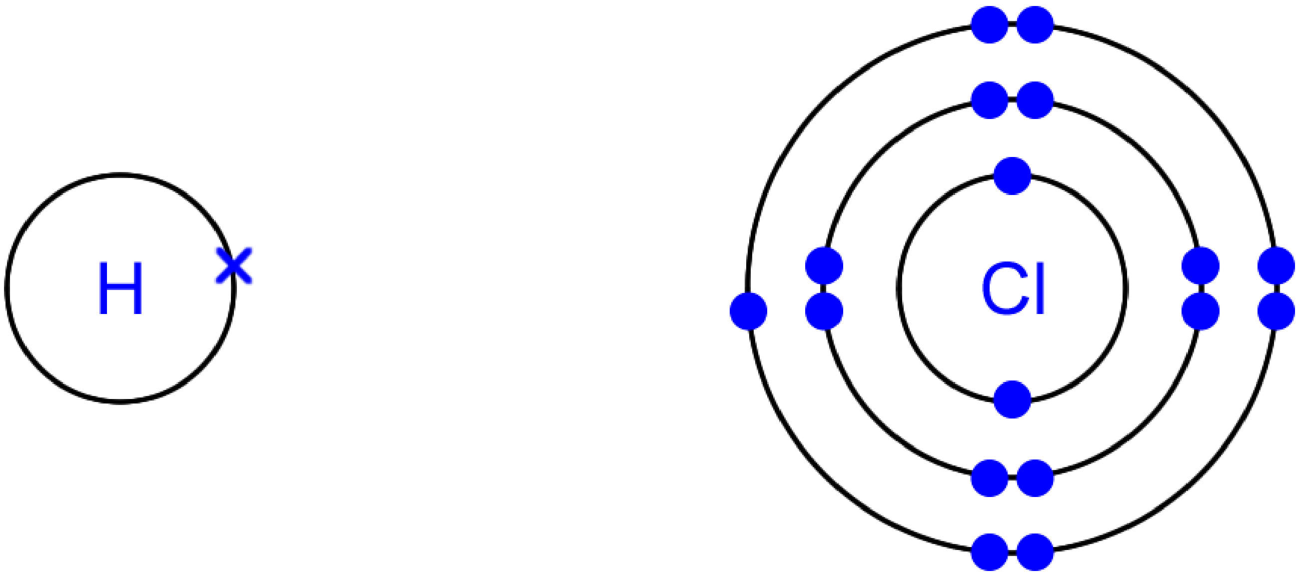
Molecule of hydrogen, formula: H_2

- The dot-and-cross diagram for molecular hydrogen that should be used as an answer in an examination.

• = Electron of hydrogen (right-hand-side). × = Electron of hydrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Hydrogen Chloride



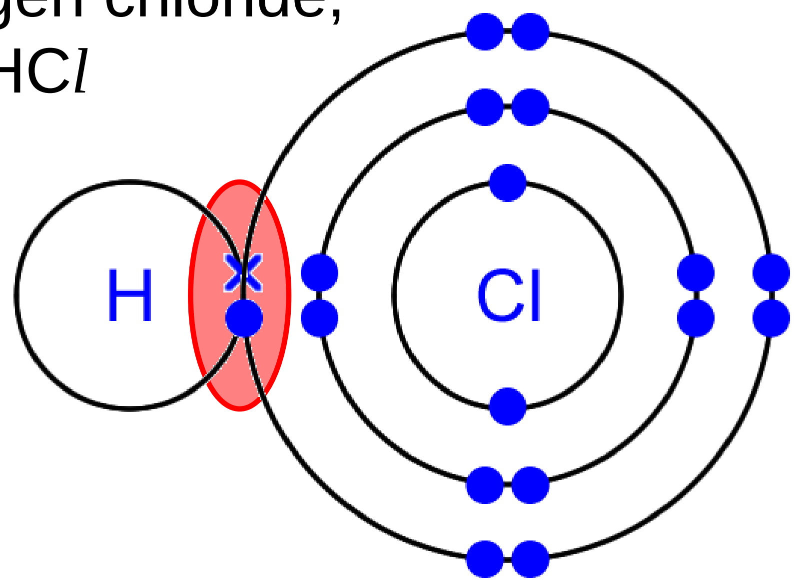
• In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of chlorine. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Hydrogen Chloride

Molecule of hydrogen chloride,
formula: HC*l*



- In *covalent bonding*, atoms of the *non-metallic* elements must *join together* and *share electrons* in order for every atom to obtain a *noble gas electronic configuration*. **Note:** a covalent bond is a *shared pair of electrons*.

• = Electron of chlorine. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Hydrogen

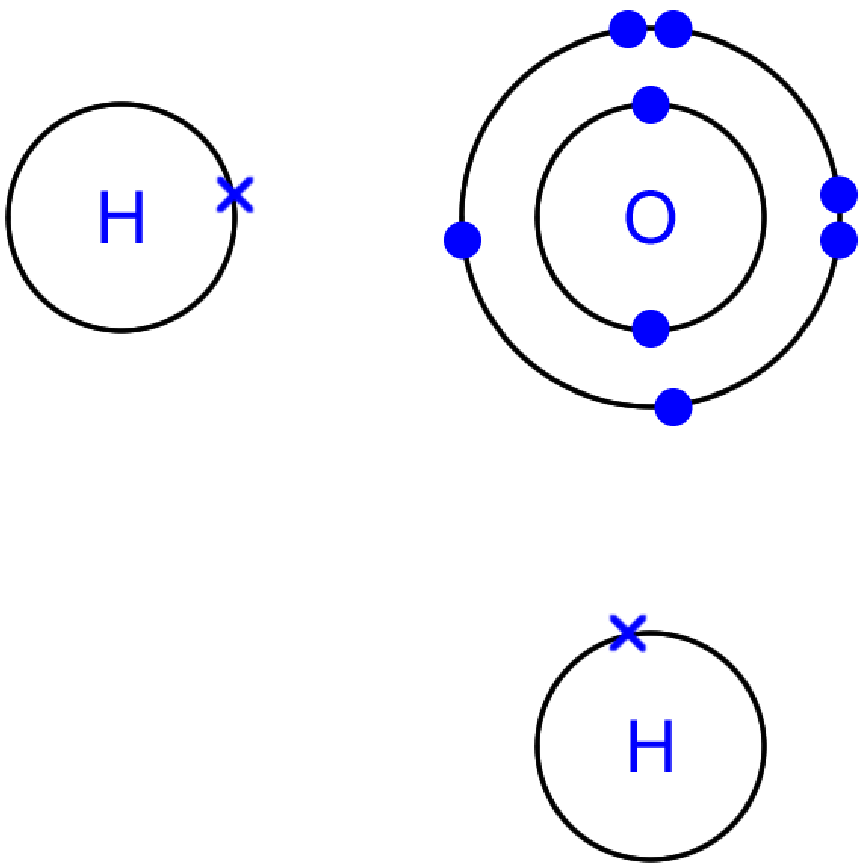
Molecule of hydrogen chloride, formula: HCl

- The dot-and-cross diagram for hydrogen chloride that should be used as an answer in an examination.

• = Electron of chlorine. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Water

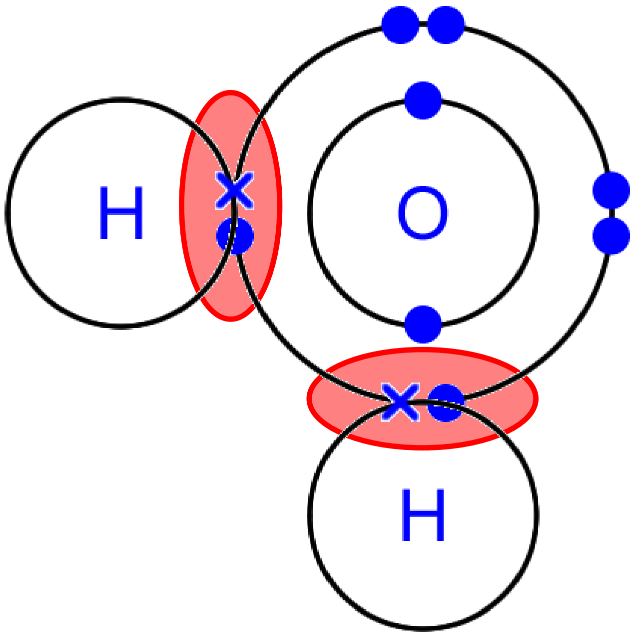


• = Electron of oxygen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Water

Molecule of water, formula: H_2O

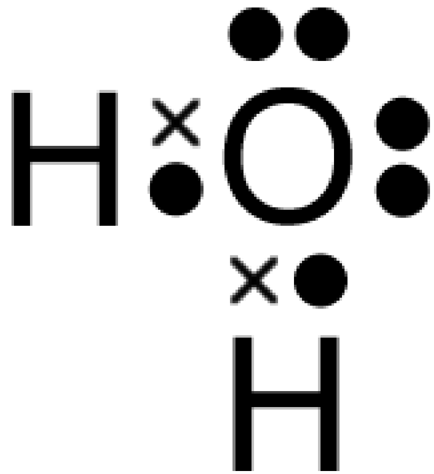


● = Electron of oxygen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Water

Molecule of water, formula: H_2O

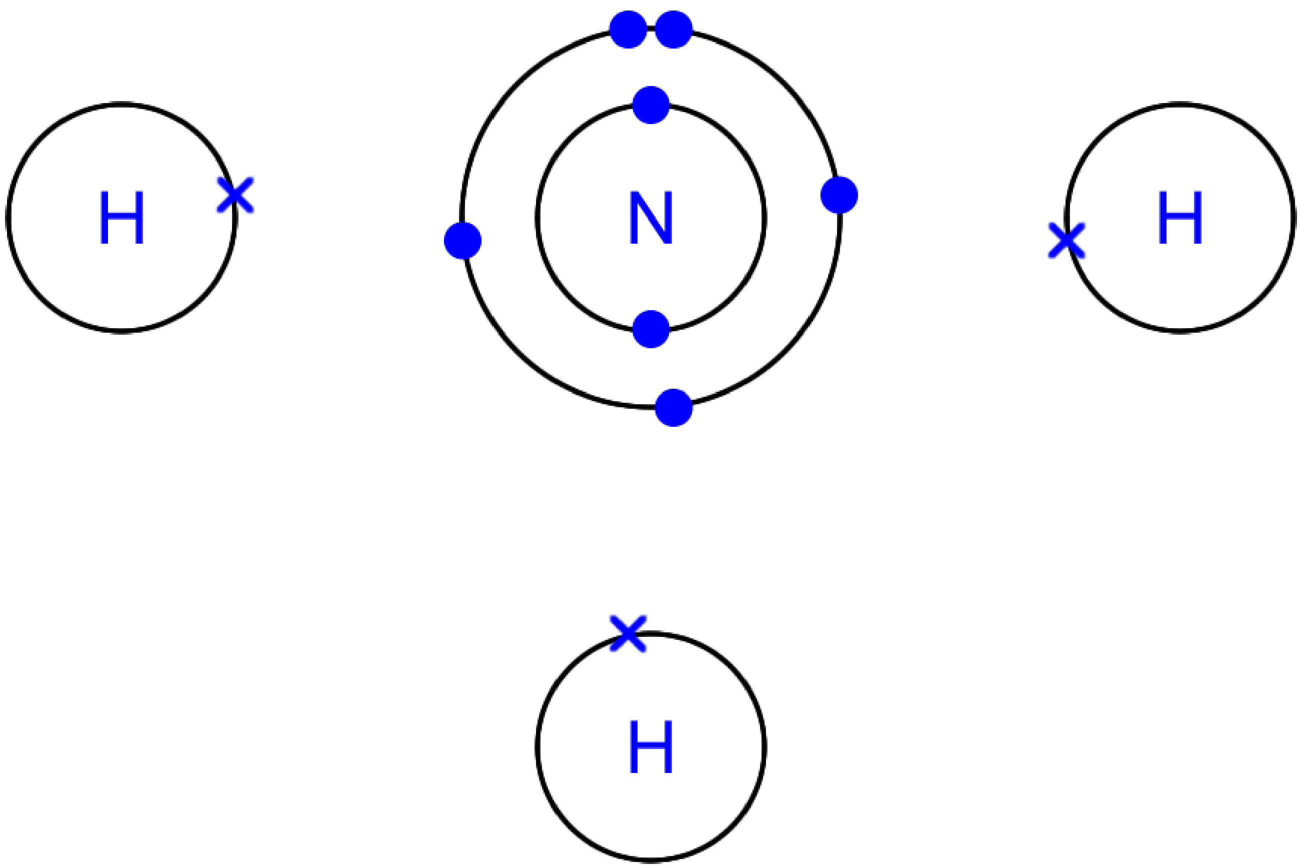


- The dot-and-cross diagram for water that should be used as an answer in an examination.

• = Electron of oxygen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Ammonia

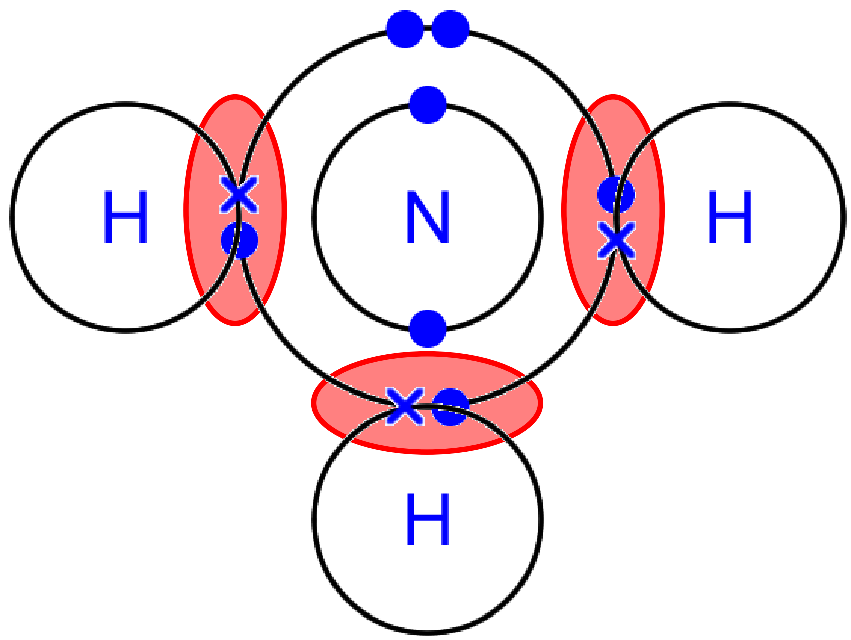


● = Electron of nitrogen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Ammonia

Molecule of ammonia, formula: NH_3

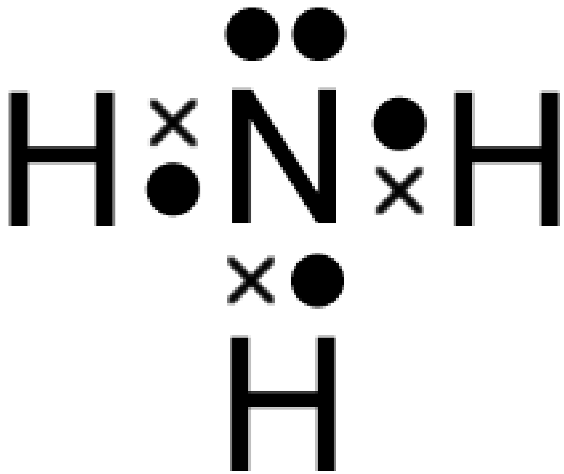


• = Electron of nitrogen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Ammonia

Molecule of ammonia, formula: NH_3

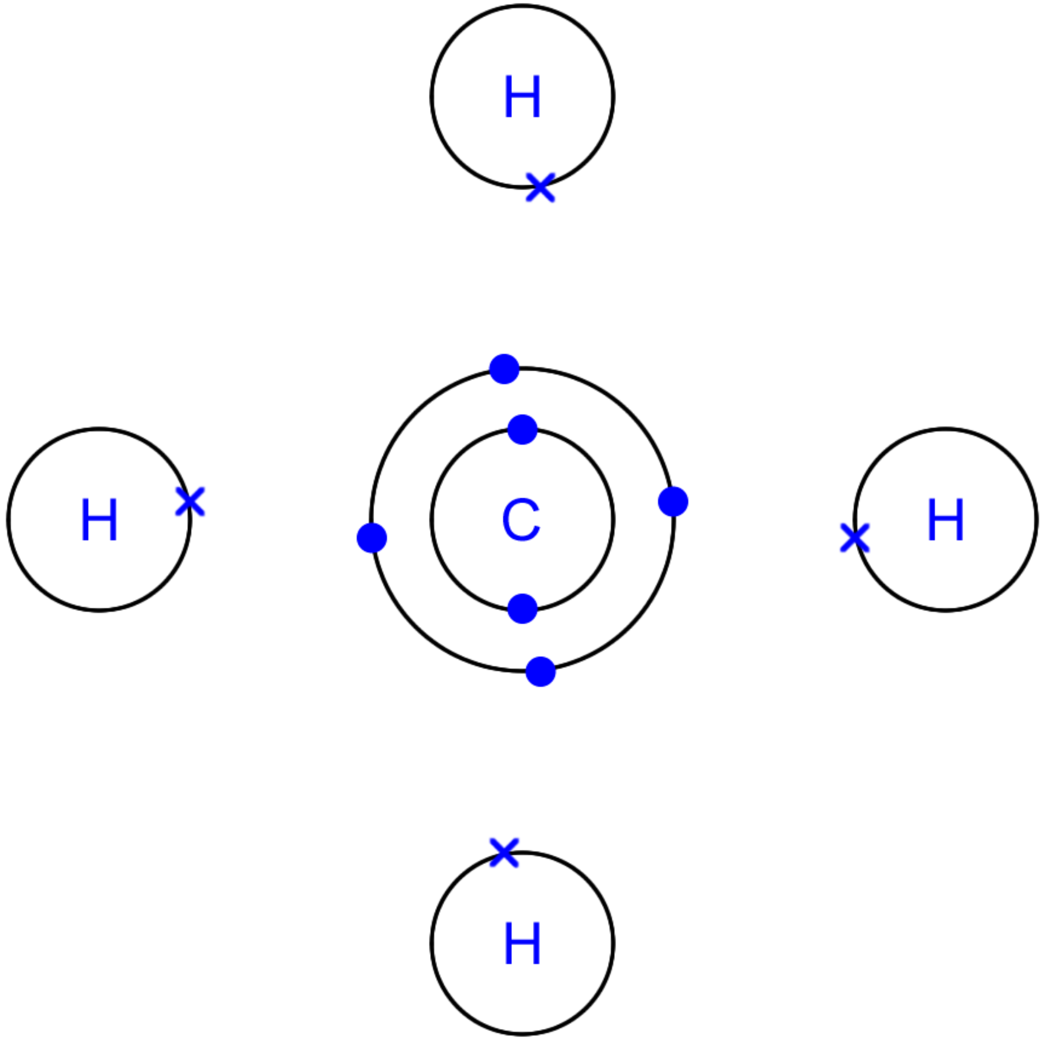


- The dot-and-cross diagram for ammonia that should be used as an answer in an examination.

• = Electron of nitrogen. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Methane

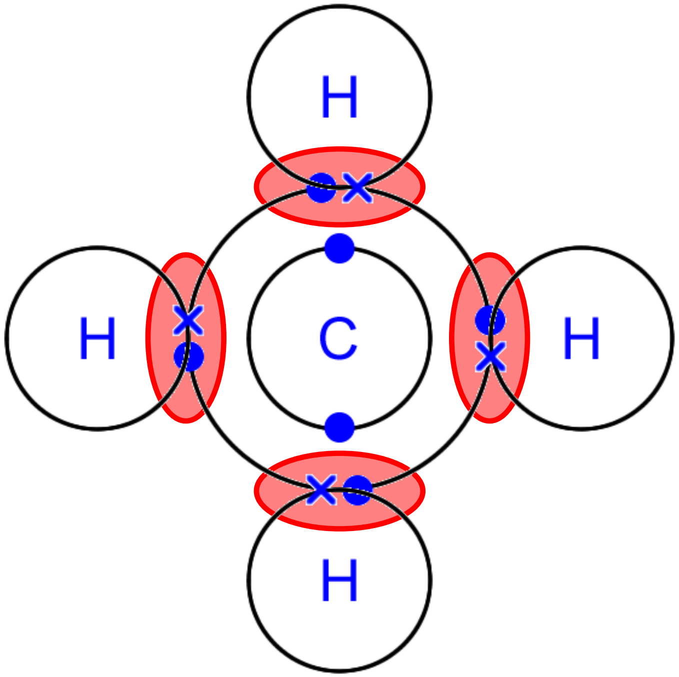


● = Electron of carbon. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Methane

Molecule of methane, formula: CH_4

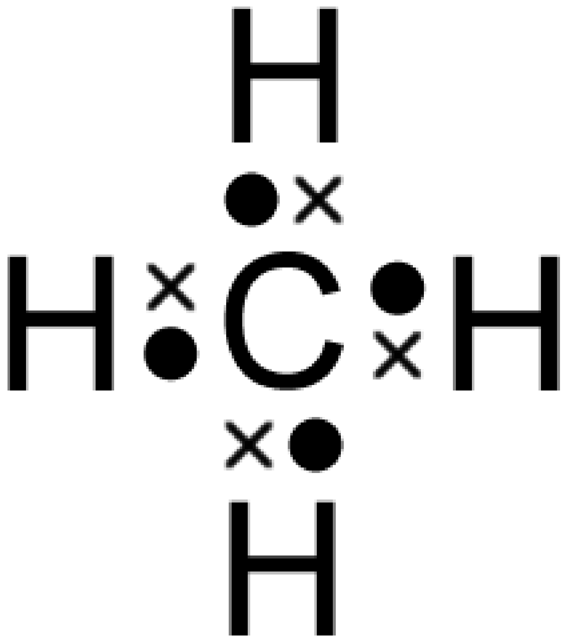


• = Electron of carbon. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding – Methane

Molecule of methane, formula: CH_4

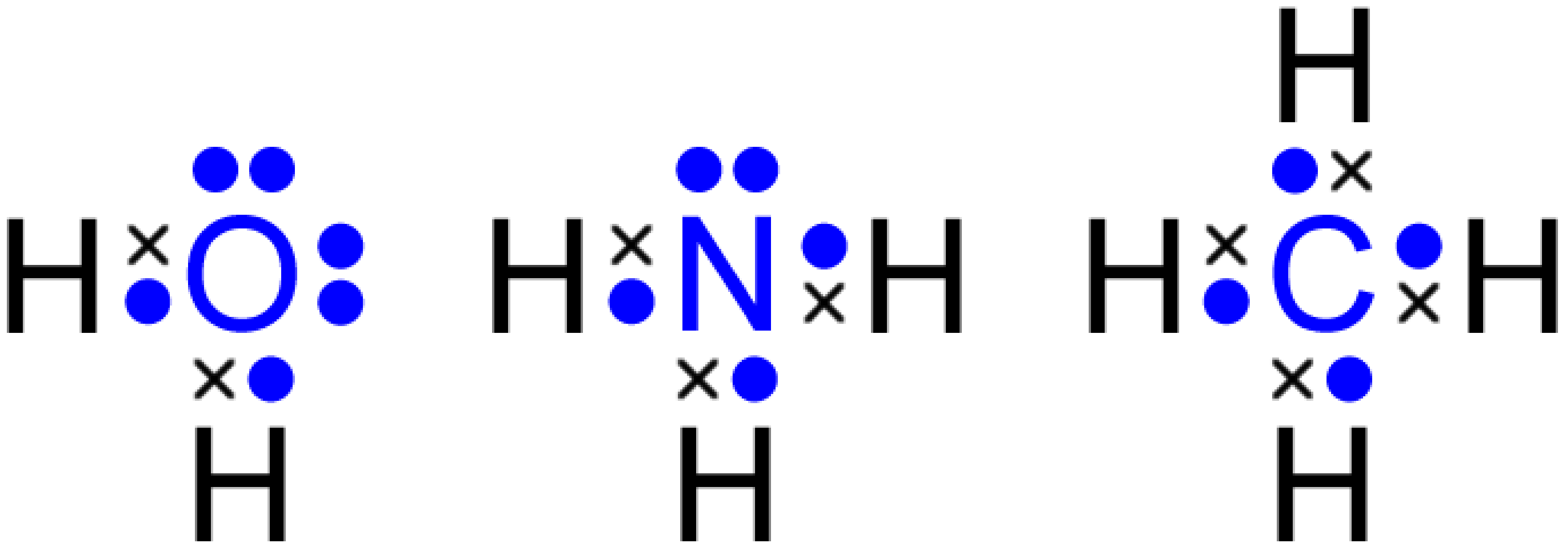


- The dot-and-cross diagram for methane that should be used as an answer in an examination.

• = Electron of carbon. × = Electron of hydrogen.

Chemical Bonding

Covalent Bonding



- **Note**: For *covalent compounds*, atom(s) of the chemical element present in the *smallest* number are usually drawn at the *centre* of the molecule. Atoms of the chemical element(s) present in *larger* numbers are then bonded around the *outside*.

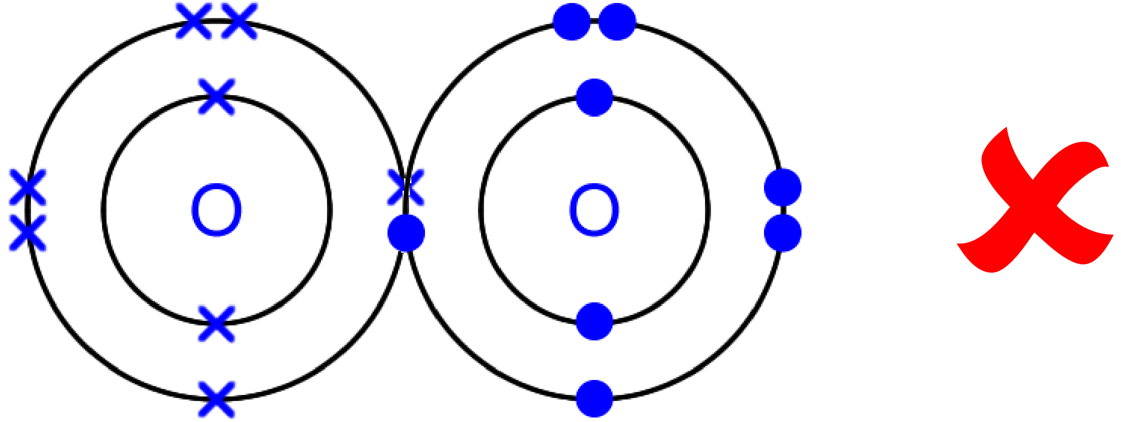
Chemical Bonding

Covalent Bonding – Oxygen

• = Electron of oxygen (right-hand-side). × = Electron of oxygen (left-hand-side).

Chemical Bonding

Covalent Bonding – Oxygen

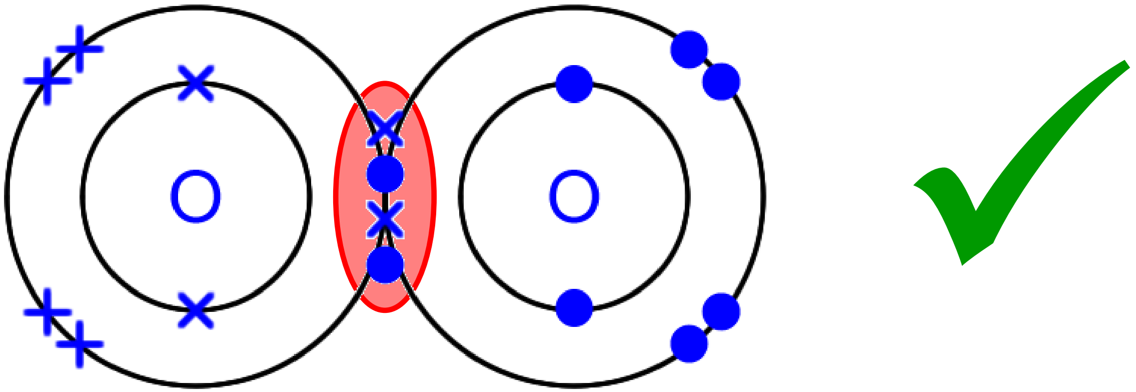


● = Electron of oxygen (right-hand-side). × = Electron of oxygen (left-hand-side).

Chemical Bonding

Covalent Bonding – Oxygen

Molecule of oxygen, formula: O_2



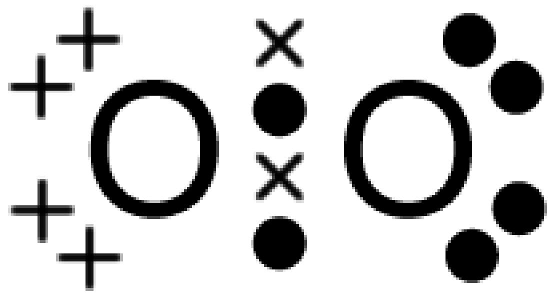
- **Note:** *Double covalent bond*.

• = Electron of oxygen (right-hand-side). × = Electron of oxygen (left-hand-side).

Chemical Bonding

Covalent Bonding – Oxygen

Molecule of oxygen, formula: O_2

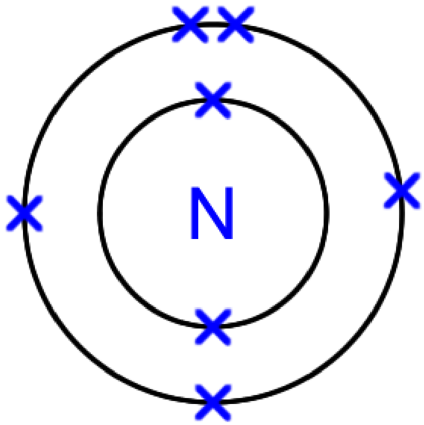


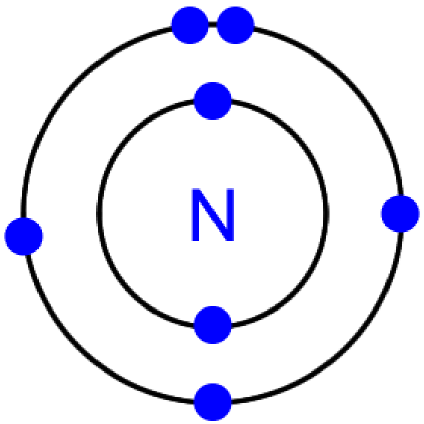
- The dot-and-cross diagram for molecular oxygen that should be used as an answer in an examination.

• = Electron of oxygen (right-hand-side). × = Electron of oxygen (left-hand-side).

Chemical Bonding

Covalent Bonding – Nitrogen

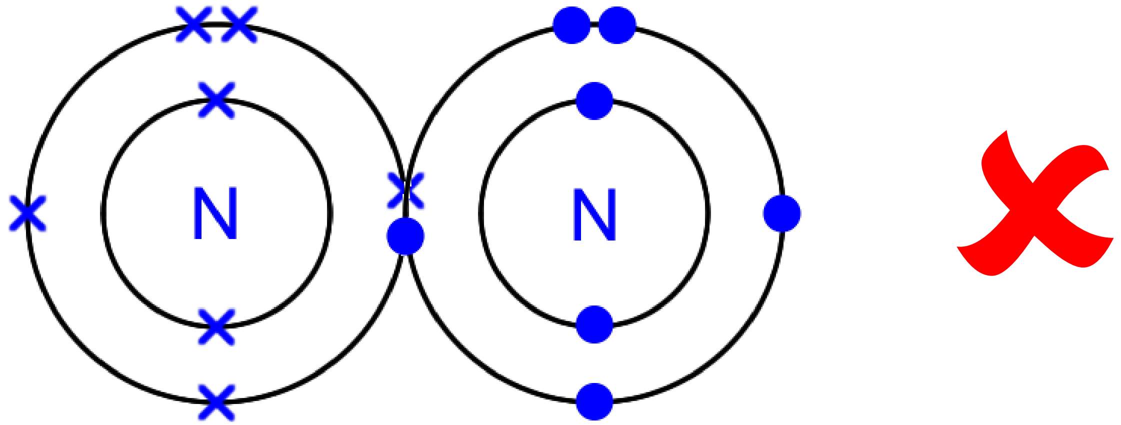




● = Electron of nitrogen (right-hand-side). × = Electron of nitrogen (left-hand-side).

Chemical Bonding

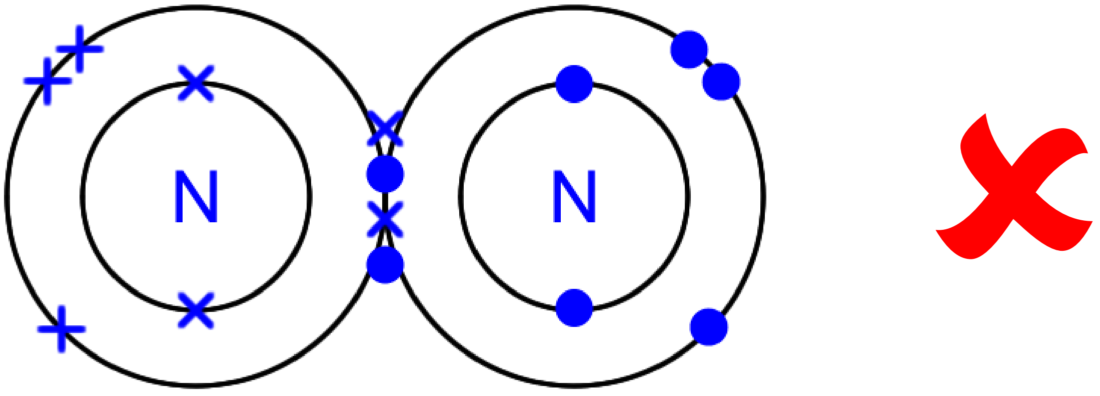
Covalent Bonding – Nitrogen



● = Electron of nitrogen (right-hand-side). × = Electron of nitrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Nitrogen

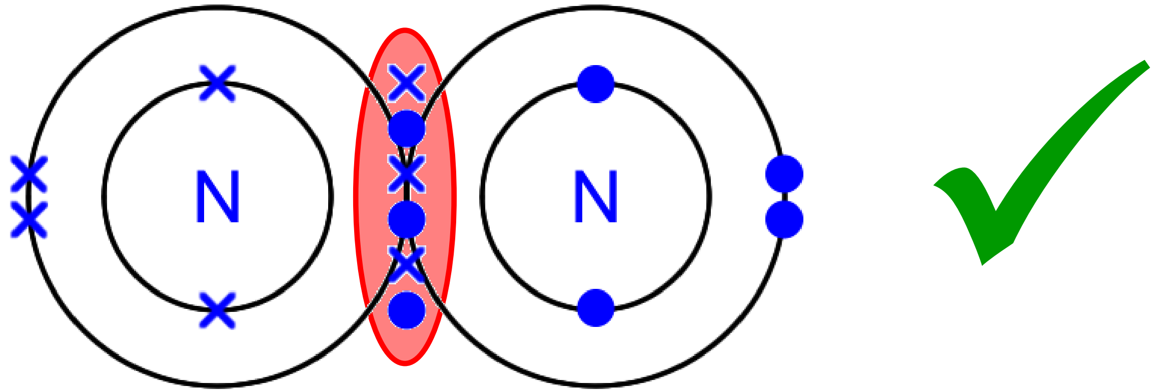


• = Electron of nitrogen (right-hand-side). × = Electron of nitrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Nitrogen

Molecule of nitrogen, formula: N_2



- **Note:** *Triple covalent bond*.

• = Electron of nitrogen (right-hand-side). × = Electron of nitrogen (left-hand-side).

Chemical Bonding

Covalent Bonding – Nitrogen

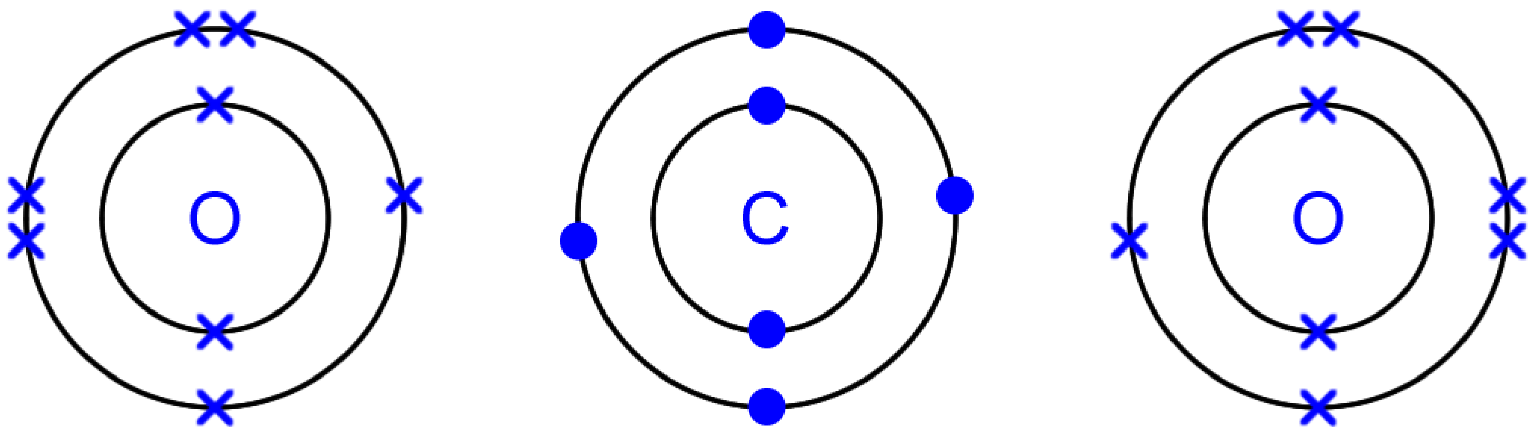
Molecule of nitrogen, formula: N_2

- The dot-and-cross diagram for molecular nitrogen that should be used as an answer in an examination.

• = Electron of nitrogen (right-hand-side). × = Electron of nitrogen (left-hand-side).

Chemical Bonding

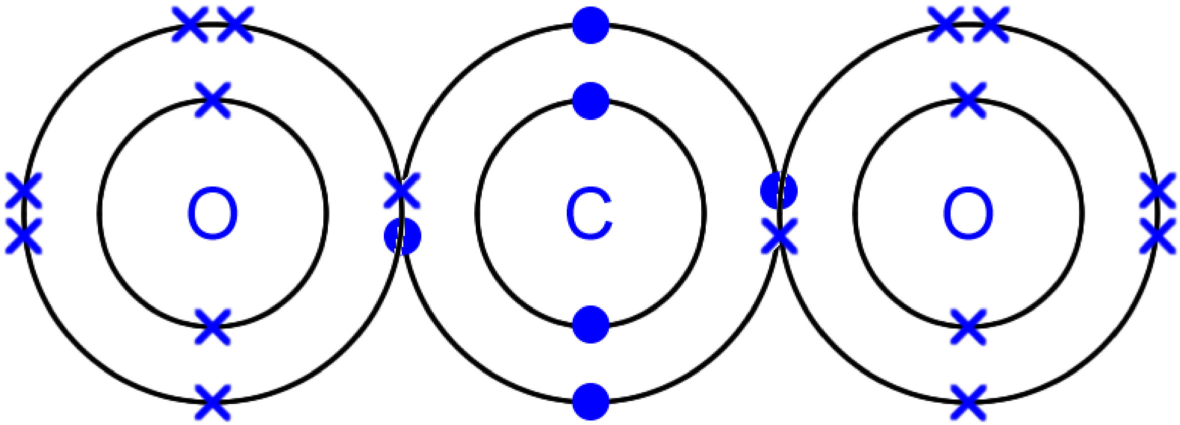
Covalent Bonding – Carbon Dioxide

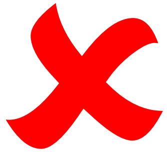


● = Electron of carbon. × = Electron of oxygen.

Chemical Bonding

Covalent Bonding – Carbon Dioxide



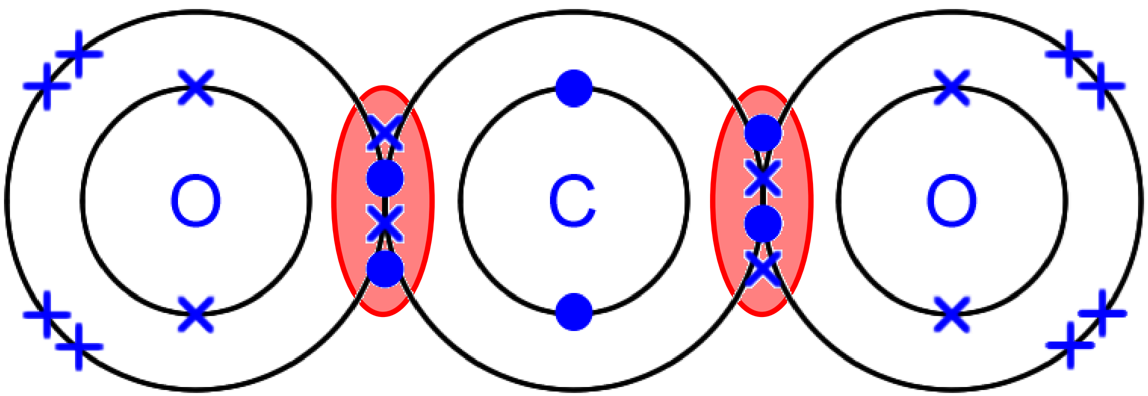


● = Electron of carbon. × = Electron of oxygen.

Chemical Bonding

Covalent Bonding – Carbon Dioxide

Molecule of carbon dioxide, formula: CO_2



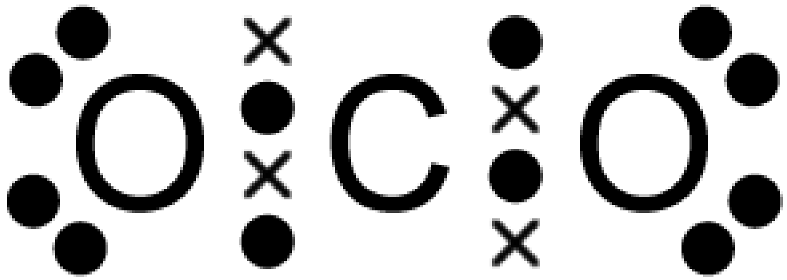
- **Note:** Two *double covalent bonds*.

• = Electron of carbon. × = Electron of oxygen.

Chemical Bonding

Covalent Bonding – Carbon Dioxide

Molecule of carbon dioxide, formula: CO_2



- The dot-and-cross diagram for carbon dioxide that should be used as an answer in an examination.

• = Electron of oxygen. × = Electron of carbon.

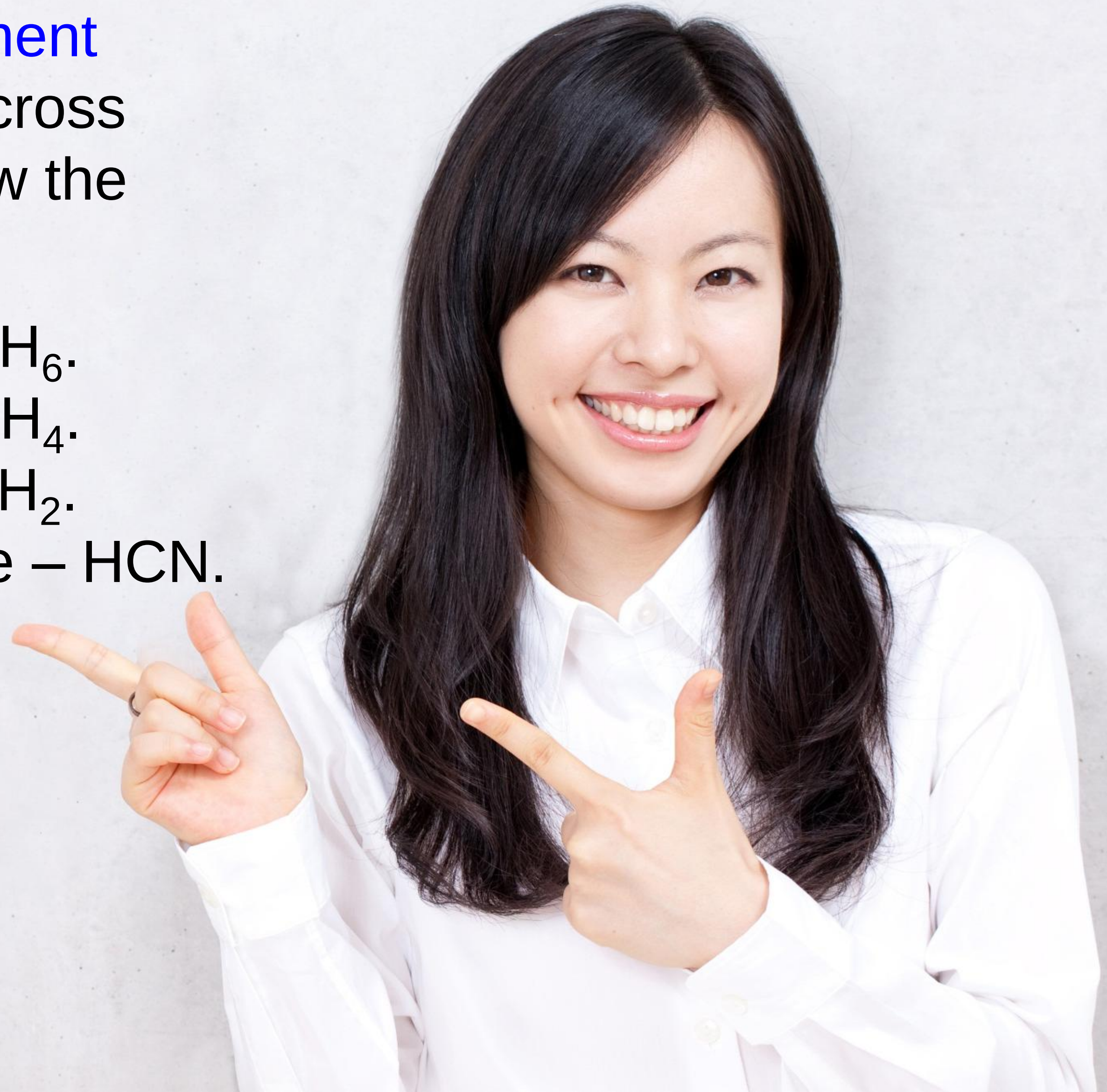
Chemical Bonding

Covalent Bonding

6. Self-assessment

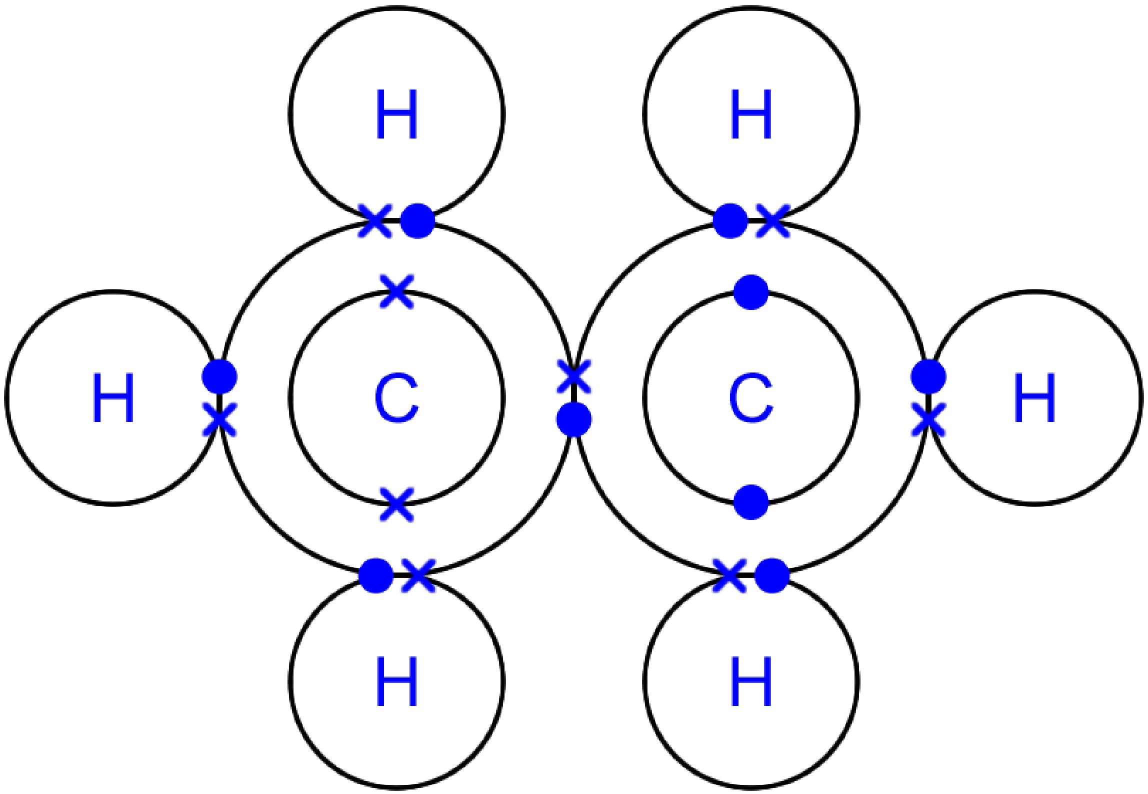
- Draw dot-and-cross diagrams to show the bonding in:

a) Ethane – C_2H_6.
b) Ethene – C_2H_4.
c) Ethyne – C_2H_2.
d) Hydrogen cyanide – HCN.



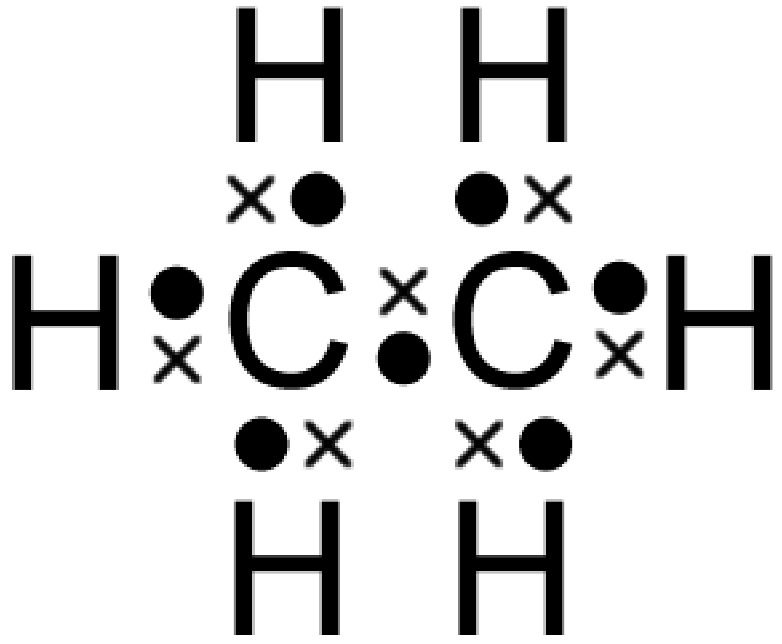
Chemical Bonding

Covalent Bonding – Ethane – C_2H_6



Chemical Bonding

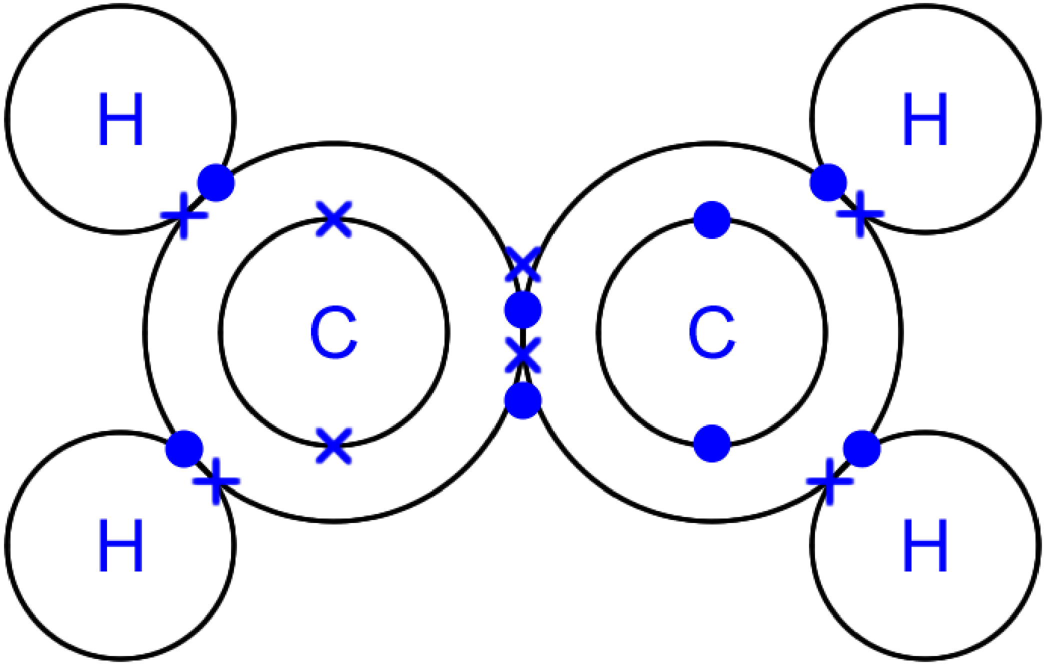
Covalent Bonding – Ethane – C_2H_6



- The dot-and-cross diagram for ethane that should be used as an answer in an examination.

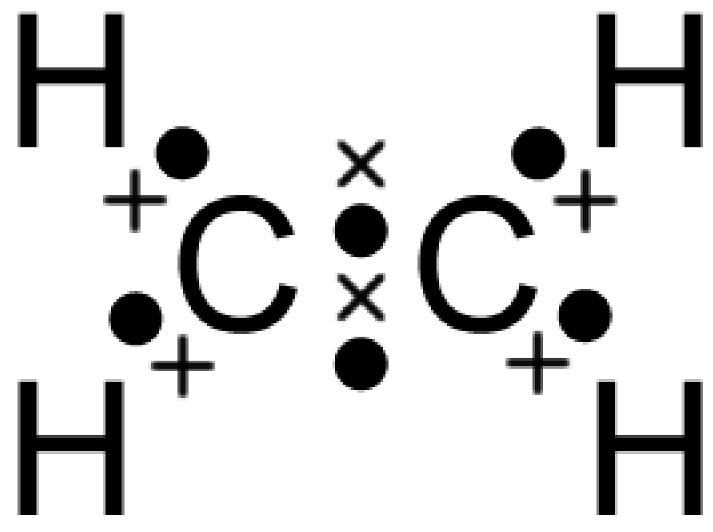
Chemical Bonding

Covalent Bonding – Ethene – C_2H_4



Chemical Bonding

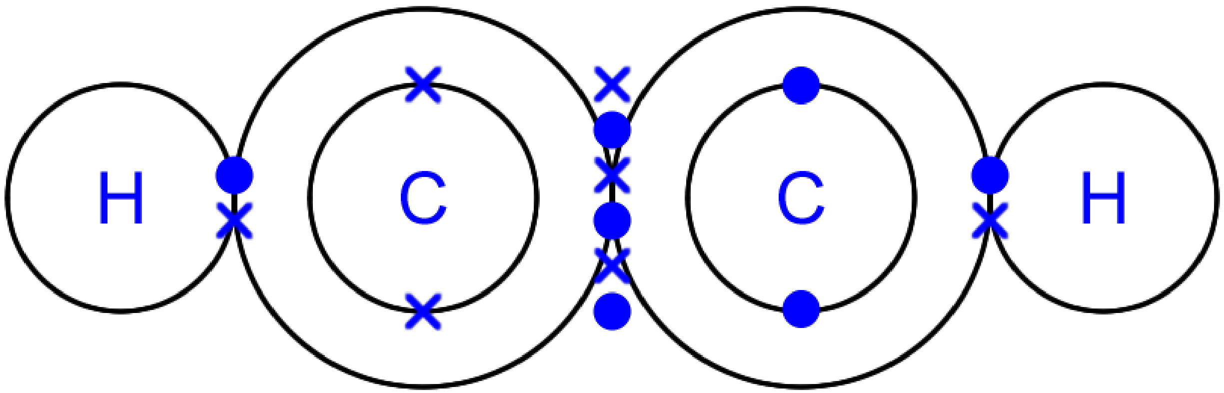
Covalent Bonding – Ethene – C_2H_4



- The dot-and-cross diagram for ethene that should be used as an answer in an examination.

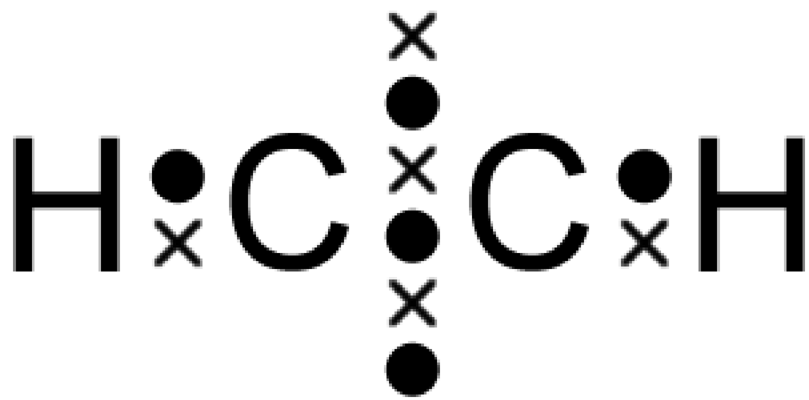
Chemical Bonding

Covalent Bonding – Ethyne – C_2H_2



Chemical Bonding

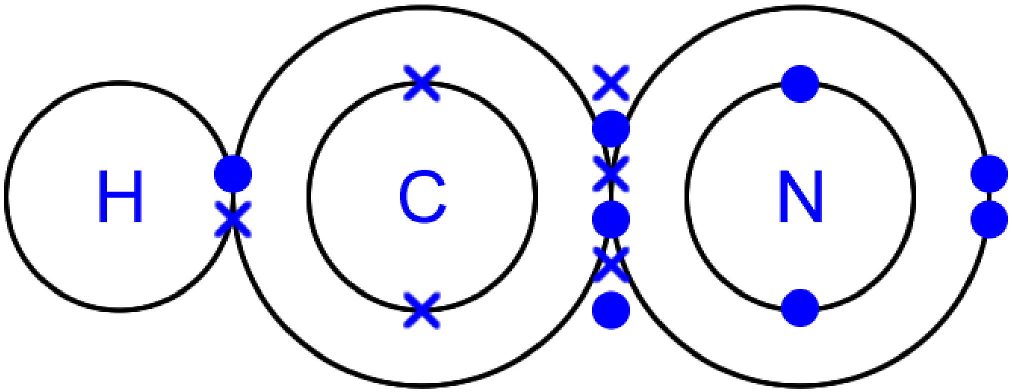
Covalent Bonding – Ethyne – C_2H_2



- The dot-and-cross diagram for ethyne that should be used as an answer in an examination.

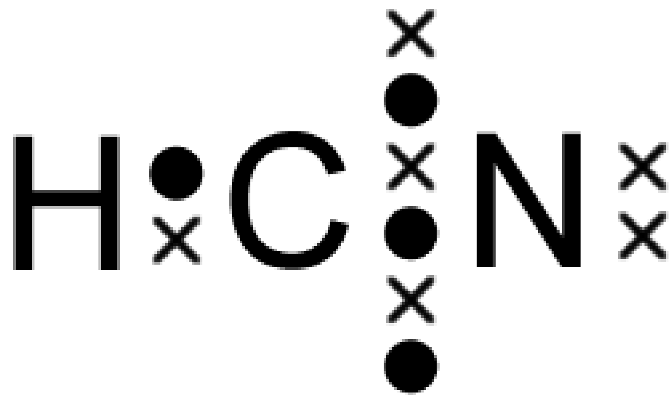
Chemical Bonding

Covalent Bonding – Hydrogen Cyanide – HCN



Chemical Bonding

Covalent Bonding – Hydrogen Cyanide – HCN



- The dot-and-cross diagram for hydrogen cyanide that should be used as an answer in an examination.

Chemical Bonding

Covalent Bonding – Summary

- Covalent bonding occurs between atoms of *non-metallic elements*.
- Atoms of the non-metallic elements *share* their valence electrons.
- Atoms of all of the non-metallic elements obtain *noble gas electronic configurations*.
- A pair of electrons that is shared equally between two atoms is referred to as a *covalent bond*.
- A covalent bond exists because the positive nuclei of two atoms are attracted towards the pair of negatively charged electrons that are equally shared between them.
- Chemicals that are composed of a relatively simple covalent structure are called *molecules*.

Chemical Bonding

Covalent Bonding – Simple Molecular – Properties

- Chemicals with a simple molecular structure have relatively *low melting points and boiling points* because the intermolecular force of attraction (or van der Waals force of attraction) between the molecules is weak and therefore only requires a small amount of thermal energy to weaken (for melting) or overcome (for boiling).

- Chemicals with a simple molecular structure (except those that are crystalline, *e.g.* iodine) tend to be *soft*.

Chemical Bonding

Covalent Bonding – Simple Molecular – Properties

- Chemicals with a simple molecular structure are generally *insoluble in polar solvents such as water*. They are, however, generally *soluble in non-polar solvents such as oil or hexane*.

- Chemicals with a simple molecular structure are *electrical insulators*, *i.e.* they do not conduct electricity in any form (solid, liquid or solution) because *they do not contain any mobile electrons or mobile ions* (*no mobile charge carrying particles*).

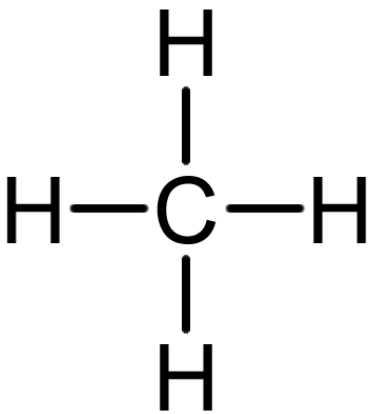
Chemical Bonding

7. In addition to dot-and-cross diagrams, what other ways of *drawing molecules* are there?

Chemical Bonding

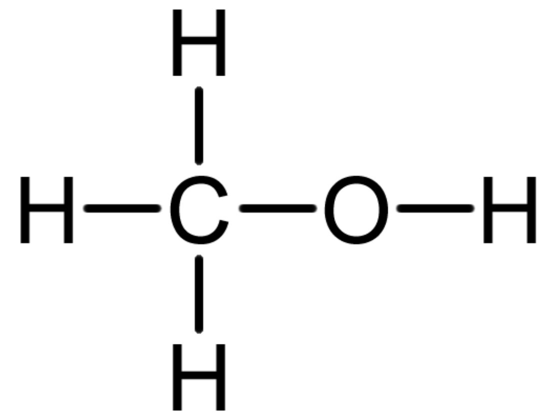
Covalent Bonding – Structural Formulae

- A structural formula is a graphical representation of the arrangement of atoms in a molecule.
- Lines are used to represent covalent bonds, *i.e.* shared pairs of electrons (dots and crosses).
- The shape of the molecule is represented by the angles between the lines / bonds.



Methane

Carbon Dioxide

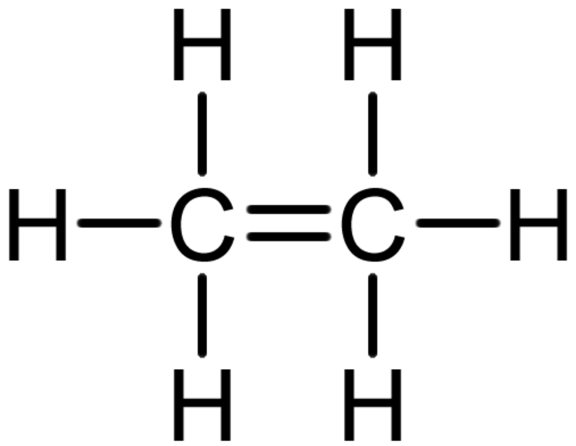


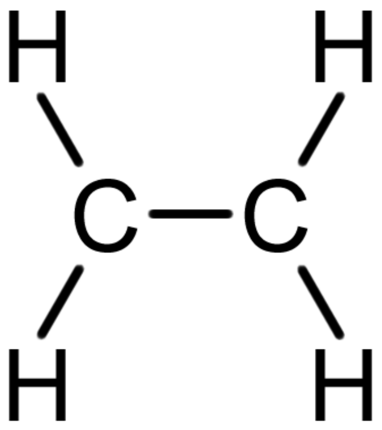
Methanol

Chemical Bonding

Covalent Bonding – Structural Formulae

- **Question:** What is wrong with the two structural formulae given below?

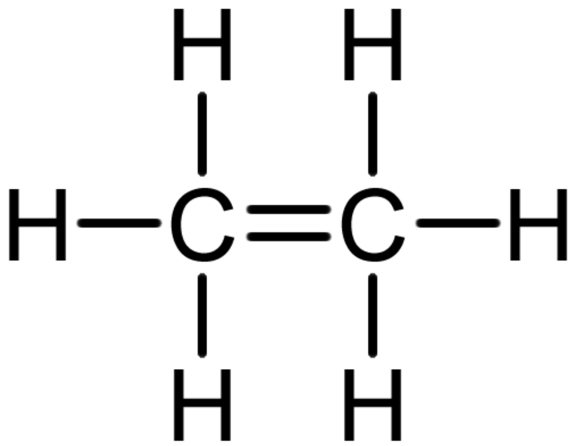


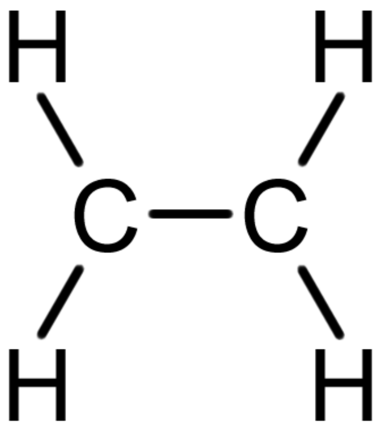


Chemical Bonding

Covalent Bonding – Structural Formulae

- **Question:** What is wrong with the two structural formulae given below?





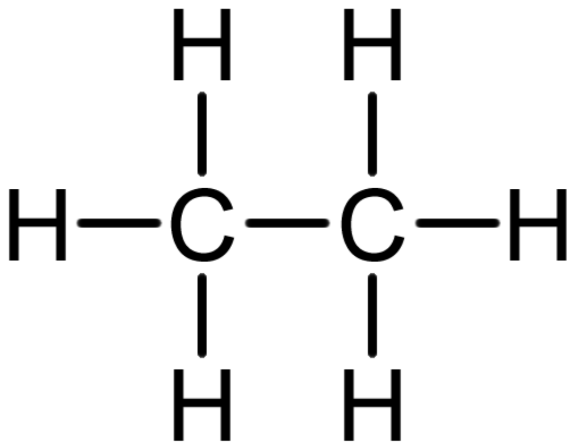
- Each carbon atom is making *five* covalent bonds. Carbon has a valency of *four* and should make *four* covalent bonds.

- Each carbon atom is making *three* covalent bonds. Carbon has a valency of *four* and should make *four* covalent bonds.

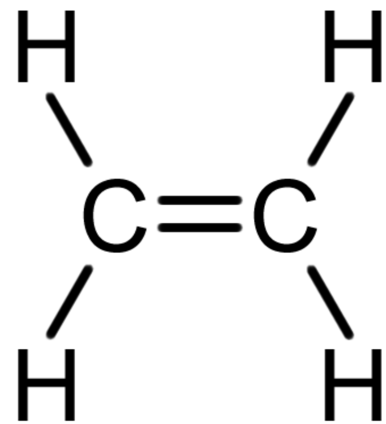
Chemical Bonding

Covalent Bonding – Structural Formulae

- The *correct* structural formulae are given below:



- The *correct* structural formula for ethane, C_2H_6. All of the carbon atoms are *tetravalent*, *i.e.* making four covalent bonds.



- The *correct* structural formula for ethene, C_2H_4. All of the carbon atoms are *tetravalent*, *i.e.* making four covalent bonds.

Chemical Bonding

8. Which chemical elements are *diatomic*?

Chemical Bonding

Diatomic Elements:

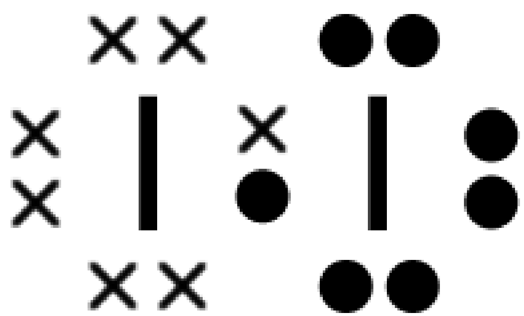
I Have No Bright Or Clever Friends

Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Iodine – I_2

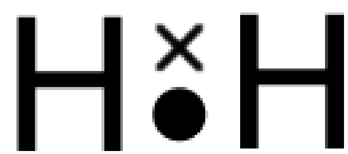


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Hydrogen – H_2

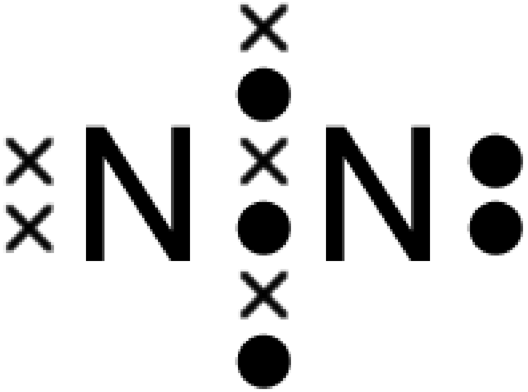


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Nitrogen – N_2

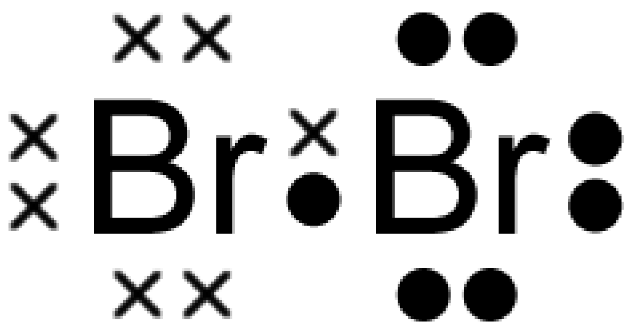


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Bromine – Br_2

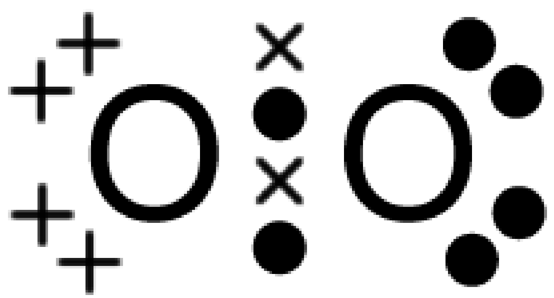


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Oxygen – O_2

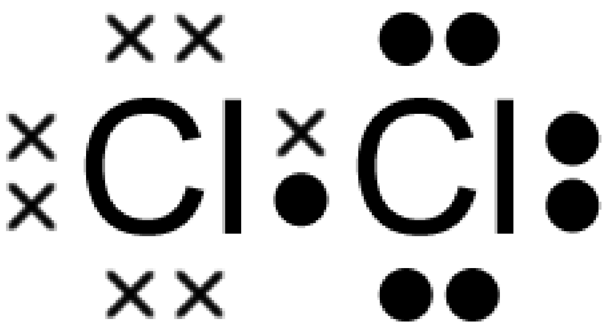


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Chlorine – Cl_2

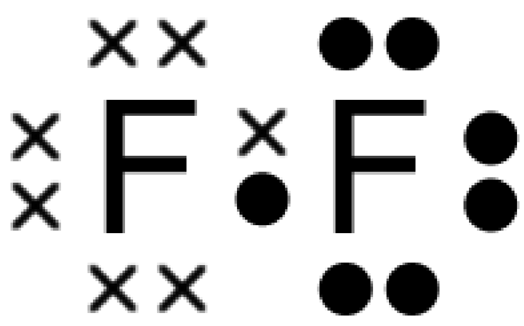


Chemical Bonding

Diatomic Elements:

I Have No Bright Or Clever Friends

Fluorine – F_2



Chemical Bonding

9. What is *electronegativity*?

Chemical Bonding

Intermolecular Forces – Electronegativity

- Definition of *Electronegativity*

→ Electronegativity is a measure of the relative tendency of an atom to attract a *bonding pair of electrons*.

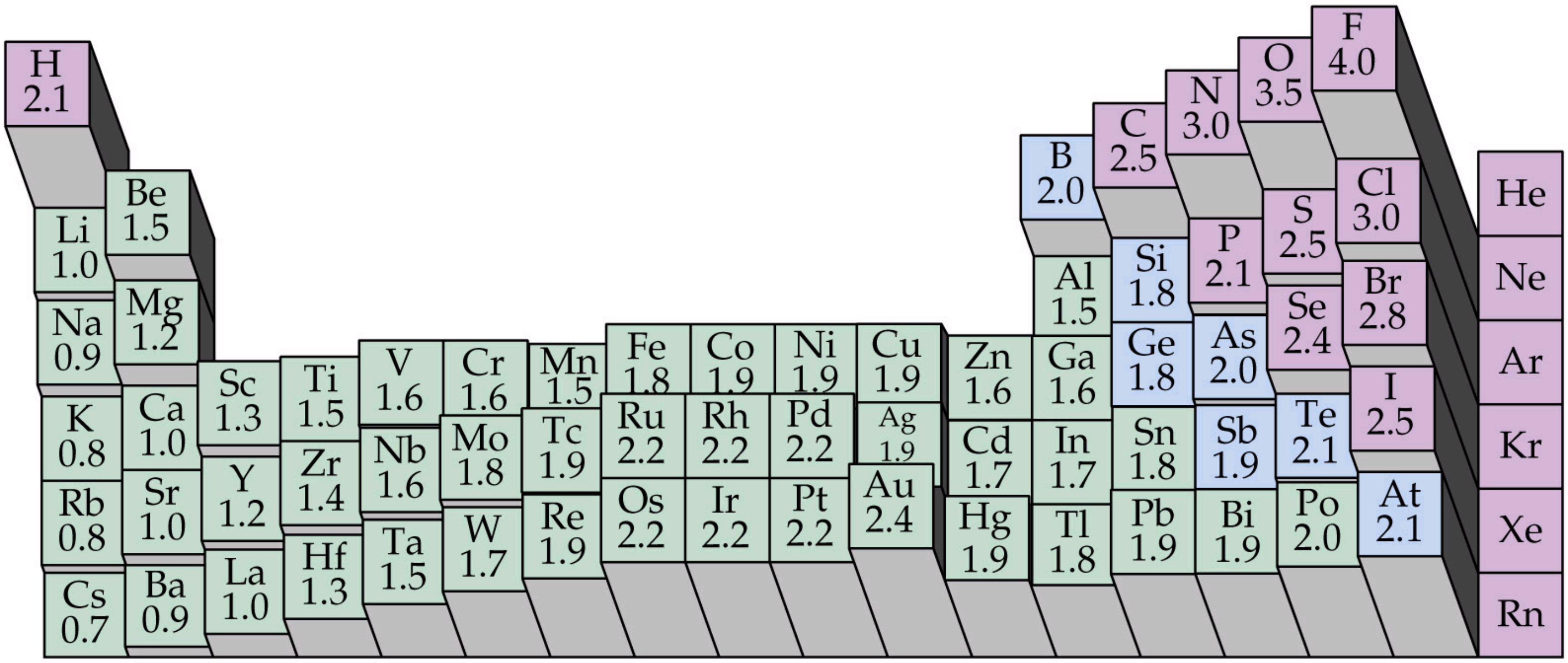
→ Electronegativity values of the chemical elements are given on a scale of 0 to 4, with 4 being the most electronegative.

→ Electronegativity values are *relative* and do not have any units.

Chemical Bonding

Intermolecular Forces – Electronegativity

- Electronegativity Values of the Chemical Elements (Pauling Scale)

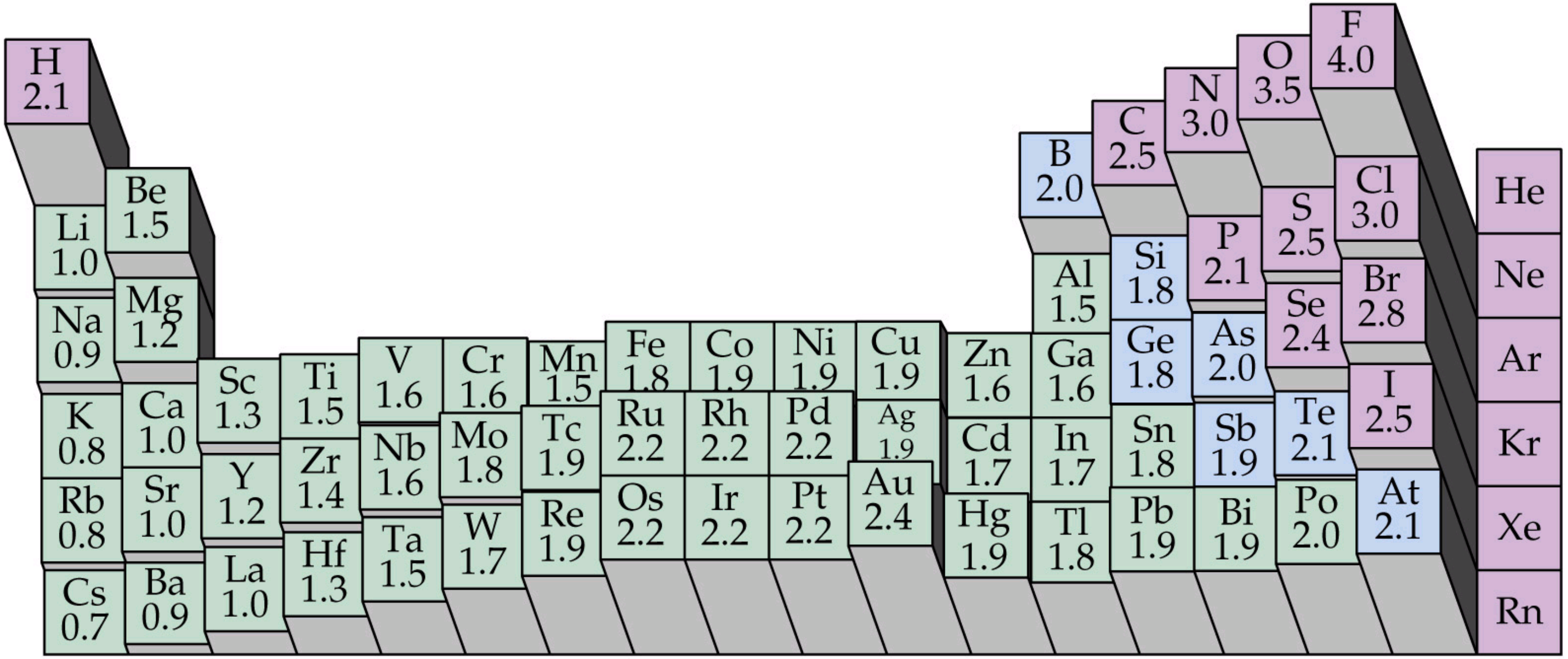


- Why are no electronegativity values assigned to the Noble Gases (Group 18)?

Chemical Bonding

Intermolecular Forces – Electronegativity

- Electronegativity Values of the Chemical Elements (Pauling Scale)



- Noble Gases are unreactive. They do not form covalent bonds, *i.e.* they do not share pairs of electrons with other atoms.

Chemical Bonding

Intermolecular Forces – Electronegativity

→ When two atoms of different elements are held together by a covalent bond, if the difference in electronegativity values of the two elements is greater than ~0.5, then the covalent bond will be *polar*.

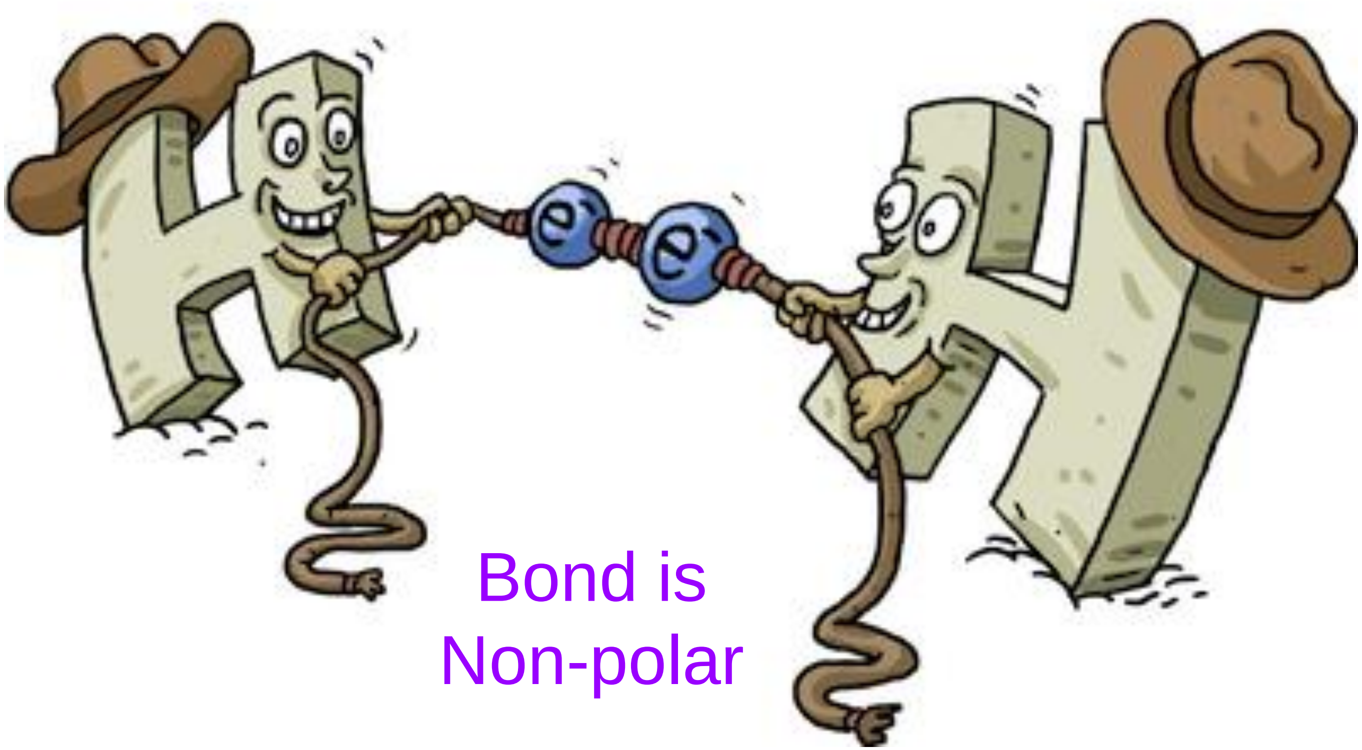
→ The atom of the element with the *greater* electronegativity value, because it is pulling the negatively charged bonding pair of electrons *towards* it, will gain a *slight negative charge*, written as $\delta-$ (delta negative).

→ The atom of the element with the *smaller* electronegativity value, because it has the negatively charged bonding pair of electrons pulled *away* from it, will gain a *slight positive charge*, written as $\delta+$ (delta positive).

Chemical Bonding

Intermolecular Forces – Electronegativity

Hydrogen = 2.1 Hydrogen = 2.1



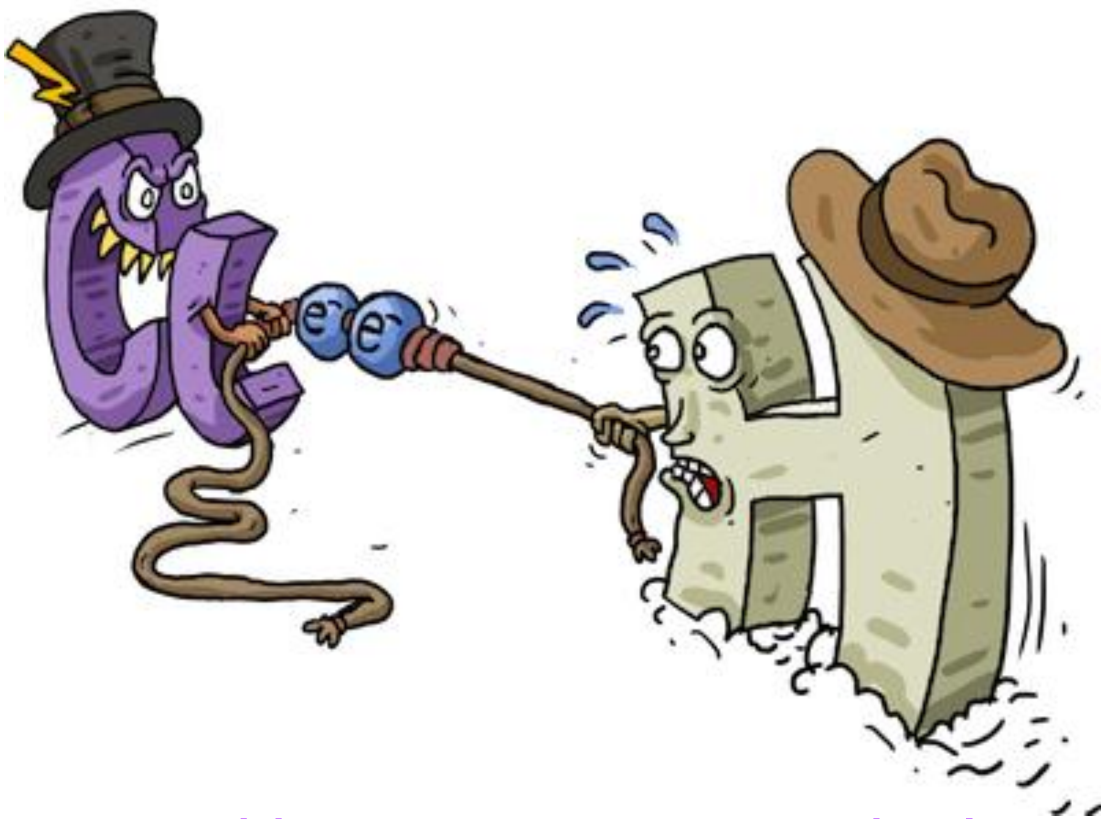
Bond is
Non-polar

Chemical Bonding

Intermolecular Forces – Electronegativity

Chlorine = 3.0 Hydrogen = 2.1

$\delta-$



$\delta+$

Bond has a Permanent Dipole

Chemical Bonding

10. Could I please have some *questions* to practice my understanding?

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
Q	9	11	9
R	12	14	12
S	8	8	10

a) Identify element **Q** and write its nuclide notation.

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
Q	9	11	9
R	12	14	12
S	8	8	10

a) Identify element **Q** and write its nuclide notation.

Answer: Number of protons = 9 $\therefore$ atomic number = 9 $\therefore$ the element is fluorine. Nuclide notation = ${}^{20}_{9}F$.

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
Q	9	11	9
R	12	14	12
S	8	8	10

b) Identify element **R** and write its nuclide notation.

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	Number of Protons	Number of Neutrons	Number of Electrons
Q	9	11	9
R	12	14	12
S	8	8	10

b) Identify element **R** and write its nuclide notation.

Answer: Number of protons = 12 $\therefore$ atomic number = 12 $\therefore$ the element is magnesium. Nuclide notation = $^{26}_{12}Mg$.

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
Q	9	11	9
R	12	14	12
S	8	8	10

c) Identify element **S** and write its nuclide notation.

Revision Questions

Question 1:

- Study the information given about the three different elements given below:

Particle	Number of Protons	Number of Neutrons	Number of Electrons
Q	9	11	9
R	12	14	12
S	8	8	10

c) Identify element **S** and write its nuclide notation.

Answer: Number of protons = 8 ∴ atomic number = 8
∴ the element is oxygen. Nuclide notation = $^{16}_{8}O^{2-}$.

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	**Electronic Configuration**
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

a) Give the formula of the compound that is formed between element **U** and element **Y**. Is the bonding in this compound ionic or covalent?

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	**Electronic Configuration**
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

a) Give the formula of the compound that is formed between element **U** and element **Y**. Is the bonding in this compound ionic or covalent?

Answer: $\mathbf{U_3Y}$ – the bonding is ionic.

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	**Electronic Configuration**
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

b) Give the formula of the compound that is formed between element **Y** and element **Z**. Is the bonding in this compound ionic or covalent?

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	Electronic Configuration
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

b) Give the formula of the compound that is formed between element **Y** and element **Z**. Is the bonding in this compound ionic or covalent?

Answer: **YZ_3** – the bonding is covalent.

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	Electronic Configuration
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

c) Give the formula of the compound that is formed between element **W** and element **Y**. Is the bonding in this compound ionic or covalent?

Revision Questions

Question 2:

- Study the information given about the four different elements given below:

Particle	**Electronic Configuration**
U	2, 8, 1
W	2, 8, 2
Y	2, 5
Z	2, 8, 7

c) Give the formula of the compound that is formed between element **W** and element **Y**. Is the bonding in this compound ionic or covalent?

Answer: $\mathbf{W_3Y_2}$ – the bonding is ionic.

Revision Questions

Question 3:

a) Draw the dot-and-cross diagram to show the arrangement of the valence electrons, and hence the bonding, between the elements shown below:

P: electronic configuration = 2, 8, 1

Q: electronic configuration = 2, 8, 6

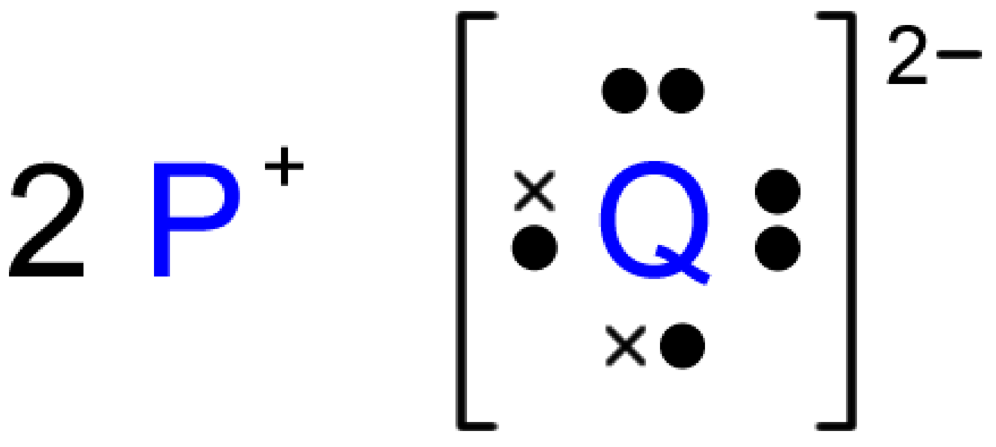
Revision Questions

Question 3:

a) Draw the dot-and-cross diagram to show the arrangement of the valence electrons, and hence the bonding, between the elements shown below:

P: electronic configuration = 2, 8, 1

Q: electronic configuration = 2, 8, 6



• = Electron of **Q**. × = Electron of **P**.

Revision Questions

Question 3:

b) Draw the dot-and-cross diagram to show the arrangement of the valence electrons, and hence the bonding, between the elements shown below:

X: electronic configuration = 2, 4

Y: electronic configuration = 2, 8, 7

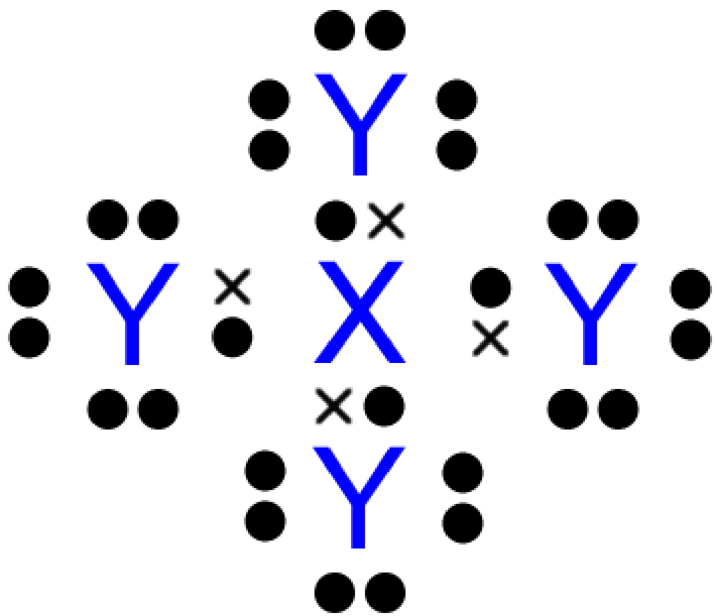
Revision Questions

Question 3:

b) Draw the dot-and-cross diagram to show the arrangement of the valence electrons, and hence the bonding, between the elements shown below:

X: electronic configuration = 2, 4

Y: electronic configuration = 2, 8, 7



• = Electron of **Y**. × = Electron of **X**.

Chemical Bonding

11. Could I please have a *summary of the different terms* that have been used?

Glossary of Terms

Atom:

- An atom is the smallest part of a chemical element that demonstrates all of the typical chemical properties of that element.

Glossary of Terms

Anion:

- An anion is a negatively charged ion, *e.g.* chloride ions (Cl^-) and oxide ions (O^{2-}) are both anions.

Glossary of Terms

Atomic Number:

- The atomic number of a chemical element equals the number of protons present in the nucleus of a single atom of the element.

Glossary of Terms

Cation:

- A cation is a positively charged ion *e.g.* sodium ions (Na^+) and magnesium ions (Mg^{2+}) are both cations.

Glossary of Terms

Compound:

- A compound is a pure substance that is formed when two or more different chemical elements react and chemically bond together. The ratio of elements in a compound is fixed, and is given by the compound's formula, *e.g.* CO_2. A compound has different properties compared to the elements from which it was formed. The elements in a compound cannot be separated by a physical process, *e.g.* chromatography or distillation.

Glossary of Terms

Covalent Bond:

- A covalent bond is the type of chemical bond that is formed when a pair of electrons is shared between the atoms of two non-metallic elements.

Glossary of Terms

Diatomic Molecule:

- A diatomic molecule is a group of two non-metallic atoms that are joined together by a covalent bond(s). Diatomic molecules can be either elements, *e.g.* chlorine (Cl_2) or compounds, *e.g.* carbon monoxide (CO).

Glossary of Terms

Electron:

- An electron is a subatomic particle with a charge of –1 and a mass of $^{1}/_{1840}$ a.m.u. (atomic mass unit) that orbits the nucleus of an atom.

Glossary of Terms

Element:

- An element is a pure substance that cannot be converted into anything more simple by a chemical process / reaction.

Glossary of Terms

Ion:

- An ion is a positively or negatively charged particle. It is formed when an atom or group of atoms loses or gains electrons.

Glossary of Terms

Ionic Compound:

- An ionic compound is formed when a metal reacts with a non-metal. The metal transfers electrons to the non-metal so that both obtain a noble gas electronic configuration. The metal forms a positively charged ion (cation) and the non-metal forms a negatively charged ion (anion). The oppositely charged ions are held together in an ordered lattice / crystal structure by strong electrostatic forces of attraction.

Glossary of Terms

Ionic Bond:

- An ionic bond is the electrostatic force of attraction between positively charged ions (cations) and negatively charged ions (anions).

Glossary of Terms

Isotope:

- Isotopes are atoms of the same chemical element that contain the same number of protons (*i.e.* the same atomic number) but a different number of neutrons (*i.e.* a different mass number). Isotopes have the same chemical properties, but slightly different physical properties.

Glossary of Terms

Mass Number:

- The mass number of a chemical element equals the total number of protons and neutrons present in the nucleus of a single atom of the element.

Glossary of Terms

Metallic Bond:

- The metallic bond is the electrostatic force of attraction between positively charged metal ions (cations) and the negatively charged delocalised electrons that surround them.

Glossary of Terms

Mixture:

- A mixture is formed when two or more chemical elements / compounds are added together but do not react and do not chemically combine together. The components of a mixture can be easily separated by a physical process such as distillation, filtration or chromatography.

Glossary of Terms

Molecule:

- A group of two or more non-metallic atoms that are joined together by a covalent bond(s). Molecules can be elements, *e.g.* chlorine (Cl_2) or compounds, *e.g.* water (H_2O).

Glossary of Terms

Neutron:

- A neutron is a subatomic particle with a charge of 0 and a relative mass of 1 a.m.u. (atomic mass unit) that is located in the nucleus of an atom.

Glossary of Terms

Polyatomic Molecule:

- A polyatomic molecule is a group of three or more non-metallic atoms that are joined together by covalent bonds. Polyatomic molecules can be either elements, *e.g.* phosphorus (P_4) or compounds, *e.g.* methane (CH_4).

Glossary of Terms

Proton:

- A proton is a subatomic particle with a charge of +1 and a relative mass of 1 a.m.u. (atomic mass unit) that is located in the nucleus of an atom.

Glossary of Terms

Valence Electrons:

- Valence electrons are electrons in the outer electron shell of an atom that used by the atom for forming chemical bonds.

Chemical Bonding

Presentation on
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