**1.7 Chemical formulae and naming of compounds**

A chemical formula is a short-hand way of writing a compound. It shows what atoms are involved in forming the compound, as the ratio in which the different atoms are combined.

## Ionic compounds

Ionic compounds are formed when charged particles, called ions, that are attracted to one another. The attraction occurs between oppositely charged particles. It is called electrostatic attraction. The net charge in the compound must be zero for a stable compound to form.

## Compounds formed from simple ions

The formula of magnesium oxide is MgO. This tells us that one atom of magnesium (in its ionic form) combines with one atom of ionic oxygen.

From the Periodic Table you would be able to see that a magnesium ion (Mg2+) has a charge of 2+, and an oxide ion (O2-) a charge of 2-. When they combine is a 1:1 ration the +2 and -2 charges neutralize one another. So there must be an equal number of each type of ion to form a neutral crystal of magnesium oxide.

The formula of aluminium oxide is Al2O3.

An aluminium ion (Al3+) has a charge of 3+, and an oxide ion (O2-) a charge of 2-, so there needs to be two aluminium ions (total charge = 2x3+ = 6+) for every three oxide ions (total charge = 3x2- = 6-) to form a neutral crystal.

### Activity x Writing formulae for simple ionic compounds

Complete the following on your own.

1. Write the formulae for each of the following ionic compounds.

potassium chloride (K+, Cl-)

sodium oxide (Na+, O2-)

lithium nitride (Li+, N3-)

magnesium fluoride (Mg2+, F-)

calcium oxide (Ca2+, O2-)

aluminium bromide (Al3+, Br-)

aluminium sulfide (Al3+, S2-)

aluminium nitride (Al3+, N3-)

copper (II) chloride (Cu2+, Cl-)

iron (III) chloride (Fe3+, Cl-)

mercury (I) oxide (Hg+, O2-)

mercury (II) oxide (Hg2+, O2-)

zinc bromide (Zn2+, Br-)

silver oxide (Ag+, O2-)

lead sulfide (Pb2+, S2-)

## Compound ions

A compound ion is formed from a number of non-metal atoms that are bonded together covalently (remember what you have learned about covalent bonds), and together have a net charge. The charge is usually negative but there is one compound ion that carries a positive charge, namely the ammonium ion. Some common compound ions are given below.

|  |  |
| --- | --- |
| **Name of compound ion** | **Formula of compound ion** |
| sulfate | SO42- |
| sulfite | SO32- |
| hydrogen sulfate (bisulphate) | HSO4- |
| nitrate | NO3- |
| nitrite | NO2- |
| carbonate | CO32- |
| hydrogen carbonate (bicarbonate) | HCO3- |
| hydroxide  | -OH- |
| permanganate | MnO4- |
| dichromate  | Cr2O72- |
| phosphate | PO43- |
| ammonium | NH4+ |
|  |  |

Note: Memorise this list: you will find it very useful.

The formula of potassium permanganate is KMnO4, because a potassium ion (K+) has a charge of 1+, and a permanganate ion (MnO4-) a charge of 1-, and so there must be an equal number of each type of ion to form a neutral crystal.

The formula of dihydrogen sulfate (sulfuric acid) is H2SO4, because a hydrogen ion (H+) has a charge of 1+, and a sulfate ion (SO42-) a charge of 2-, so there need to be two hydrogen ions for every three sulfate ions to form a neutral crystal.

The formula of calcium hydroxide is Ca(OH)2 because a calcium ion (Ca2+) has a charge of 2+ and a hydroxide ion (OH-) a charge of 1-, so there need to be two hydroxyl ions for every one calcium ion to form a neutral crystal. The brackets in the formula show that the subscript (2) refers to the whole compound ion in the brackets (OH-), not only to the last element (H).

### Activity x Writing formulae for compounds containing compound ions [h4]

Complete the following activity on your own.

Write the formulae for each of the following ionic compounds:

|  |  |  |
| --- | --- | --- |
| Compound name | Ions | Chemical formula |
| magnesium sulfate  | Mg2+, SO42- |  |
| calcium sulfite  | Ca2+, SO32- |  |
| potassium sulfate  | K+, SO42- |  |
| potassium carbonate  | K+, CO32- |  |
| sodium hydrogen carbonate (bicarbonate of soda) | Na+, HCO3- |  |
| ammonium sulfide  | NH4+, S2- |  |
| ammonium hydroxide  | NH4+, OH- |  |
| barium nitrate  | Ba2+, NO3- |  |
| lithium hydroxide (Li+, OH | Li+, OH- |  |
| aluminium hydroxide  | Al3+, OH- |  |
|  |  |  |
|  |  |  |

Naming ionic compounds

Ionic compounds that are made up of only two elements are named by giving the name of the metal first, followed by the name of the non-metal plus the suffix ‘-ide’.

 For example. NaCl is named sodium chloride.

#### **[icon]** Test yourselves

Give the names of the following ionic compounds:

|  |  |
| --- | --- |
| LiH | NaF |
| CaF2 | Al2S3 |
| KCl | CaO |
| MgO | PbO2 |
| BeCl2 | K2O |

**Macroscopic Properties of ionic substances**

Many of the behaviours of ionic substances can be explained by understanding how the substances are constructed. Ionic compounds do not exist as isolated particles (formula units) but rather as extended lattices (networks) called crystals.

Some properties that can be seen in ionic compounds include the following: high melting points, hardness, brittleness (the ability to easily break into smaller pieces). Can you also try to explain why these properties are observed using your knowledge of how an ionic crystal is structured?

Solid ionic compounds do not easily conduct electricity while solutions of ionic compounds e.g. sodium chloride (NaCl) do conduct electricity. This is because the ionic compounds breaks apart into its ions (Na+ and Cl-) when is dissolves in water and these charged particles can move around and conduct electricity.

Got it: Solid ionic substances cannot conduct electricity because the charged ions are held securely in place by electrostatic bonds. When the substance dissolves in water the ions are free to move towards electrodes of opposite charge and therefore a current can flow. Covalent compounds cannot conduct electricity even when dissolved because they do not form ions and therefore are not charged particles.

**Molecules**

Not all compounds are formed by the electrostatic attraction between ions as described above. In some cases atoms decide to share electrons rather than donate them completely.

#### **[icon]** Ask yourselves

Take chlorine a as an example. Each chlorine atom has 7 valence electrons in the outermost shell. How do you suggest that two chlorine atoms would solve their problem of an incomplete outer shell if they came together?

A possible solution would be for them to come close together and share their valence electrons so that each chlorine atom has seven of its own electrons and a share of one from the other atom. The two resulting shared electrons would now cause the atoms to be bonded together as a molecule. These types of bonds are called **covalent bonds**.

Covalent bonds form between non-metal elements. Incompletely filled valence orbitals from each atom overlap. In this way electrons are shared, so that each atom seems to have a noble gas configuration.

**[icon]** Did you know?

Molecules are made up from non-metals only. Metals are not involved in sharing electrons – they prefer to donate their electron and become ions. So metals are not present in molecules or molecular compounds and only occur in ionic compounds.

Do you remember which elements occur as molecules? (Section.., p…). Now you can go further and see that some compounds are also molecules, for example: H2O, CO2, NH3 etc.

Test yourselves

Do the following formulae represent molecules and elements or molecules and compounds?

|  |  |
| --- | --- |
| Cl2 | CH4 |
| NO | N2 |
| HCl | I2 |
| O2 | NO2 |
| P2O5 | H2 |

#### Ask yourselves

Would you expect molecules (with covalent bonds) to be good conductors of electricity? Why or why not?

You have seen that covalent bonds mean a sharing of electrons such that there are neither free electrons nor charged particles. Consequently there are not particles available to carry the current and these substances would be poor conductors of electricity.

What are giant molecules?

Some molecules have many atoms bonded together. Empirical formulae are used for these giant molecules. Diamonds are examples of giant molecules, as shown in Figure 11. Each diamond consists of very many carbon atoms bonded to one another covalently in a firm interlocking network, which makes the diamond very hard. Diamond can be referred to by its empirical formula, C.

#### **Naming Molecules**

Molecules that represent elements are named in exactly the same way as that atoms would be eg: H2 is called hydrogen and Cl2 is called chlorine. Molecules that represent compounds are named according to the following rules:

* the first atom (the one placed further to the lefton the Periodic Table) gets the atomic name
* the second atom (the one placed further to the righton the Periodic Table) gets the suffix “-ide” attached to the atomic name
* if more than one atom of a single type is present the information is given by a Greek prefix denoting number. The first four prefixes are: *mono-* (one), *di-* (two), *tri-* (three)and *tetra-* (four).

For example, SO2 is called sulfur dioxide and SO3 is called sulfur trioxide.

Test yourselves

Name the following molecules:

|  |  |
| --- | --- |
| NO2  | I2O4 |
| CO2  | CO |
| HCl  | PH3 |
| N2O4  | P2I4 |
| P4S3  | HF |

Did you know?

Some molecular compounds have kept their old names and do not follow the rules for naming that you have been following above. For example, NH3 is called ammonia and H2O is called water. What would their names be if we followed the rules? Nobody would know what you were talking about if you used those names whereas everyone knows exactly what you mean when you talk about water.

# Metallic bonds

We have seen how compounds are bonded together either by means of ionic bonds or covalent bonds. We have also seen how some non-metal elements exist as covalently bonded molecules.

You already know that the valence electrons of metal atoms can easily be removed. Metal atoms hold their valence electrons loosely and form positive ions as these electrons are lost. In a metallic bond, positive metal ions are embedded in a ‘sea’ of ‘communal’ **[footnote** – the electrons are communally owned: they belong to all the positive ions**]**, delocalised **[ital][footnote**- the electrons are delocalised **[bold]**: they have each been removed from the single atom to which they used to be belong.] electrons that are free to flow between the positive ions (Figure ).

**[figure: metal ions held together in a metallic bond]**

What we have not yet discussed is how metal atoms are held together.

The metal ions may all consist of the same element, for example the copper ions in a copper rod, or they may consist of different elements, for example the iron and manganese in steel. When two or more different metals are bonded together we call the resulting substance an alloy, which is classed as a type of solution.

### Activity x Explaining the properties of metals

Thinks about the metallic bonding model as a way of explaining the following characteristics of metals:

* good conduction of electricity
* good conduction of heat
* flexibility – can it bend?

**[icon]** Did you know?

The shininess of a metal can be explained as the reflection of light because of the free movement of its ‘sea’ of electrons. These electrons receive light that strikes them. This makes them vibrate. They do this freely, thus releasing most of this energy again in the form of light, which shines away from the metal.

**Intramolecular and intermolecular bonds**

You have already seen that there are different kinds of bonds which hold the atoms together. These are called **intramolecular bond**s because they occur between the atoms involved in forming a single unit. By now you are able to recognise three types of intramolecular bonds: ionic bonds, covalent bonds and metallic bonding.

# Intermolecular bonds

Intermolecular bonds hold molecules together, forming a large complex of many individual molecules. Intermolecular bonds are much weaker than metallic, ionic and covalent bonds. The strength of an intermolecular bond depends on the type of molecules and their temperature, and determines properties such as density and phase.

**[insert figure Intermolecular bonds]**

#### Did you know?

‘Inter-‘ means ‘between’. Intermolecular bonds are between molecules. ‘Intra-’ means ‘within’. Intra-molecular (covalent) bonds are within molecules. This is shown in figure 12.

### Activity x Identifying the three physical states of matter [h4]

you will need

a few small objects such as beads/stones/balls of paper

a container with a lid.

1.Read the following information.

**[different font]**

Solid, liquid and gas phases are three physical states of matter. Phase changes (changes between these three states) are physical, not chemical changes. This means that a substance does not change into another substance when changing phase. This means that covalent bonds are not broken or formed during a phase change, instead it is intermolecular bonds that are weakened or strengthened.

Particles are always moving. As heat is added to them, they move faster, and so their kinetic energy (energy due to motion) increases, and this is measured as a rise in temperature.

When particles are packed closely together we say they are more densely packed than when there are bigger spaces between the particles.

**[end font]**

2. Now simulate the three phases of matter by following these instructions.

a) Put the objects into the container and shake very softly. The objects should move so little that each should not move from its place. This has similarities to the water particles in solid water (ice).

b) Now shake the container a little harder. The objects should move enough for them to swap places with one another, but should not bounce high above the bottom of the container. This has similarities to the water particles in liquid water.

c) Make sure the lid is on the container, and then shake it as hard as you can. The objects move around the whole container. This has similarities to the water particles in gaseous water (water vapour).

3. Now match each description in the block with the relevant picture that follows.

[**insert A/W ice/ steam containers – strong intermolecular bonds/weak bonds]**

### Activity x Summative assessment

SUMMATIVE ASSESSMENT UNIT 2

### Activity??: Summative Assessment

It may be necessary to refer to a Periodic Table when answering some of these questions. See page ??

1. Give the correct term for each of the following:
a) positively charged subatomic particles
b) neutral (uncharged) subatomic particles
c) particles found in the nucleus of an atom (one word only)
d) negatively charged subatomic particles
 (4)
2. Say whether each of the following is true or false. Correct any false statement.
a) a neutral atom always contains as many protons as electrons
b) every carbon atom has 6 protons
c) every carbon atom has 6 neutrons
d) all molecules consist of two or more atoms bonded together
e) each p-orbital can contain up to six electrons (5)
3. Refer to the two nuclei pictured alongside
a) Both of these belong to Boron atoms. How do you know this? (1)
b) Give the mass of atom (i), in amu. (1)
c) Give the mass of atom (ii), in amu. (1)
d) Which of these differs between the two nuclei:
 atomic number or atomic mass? (1)
e) Complete: These are two \_\_\_\_\_\_\_\_ of Boron. (1)

2.32This is from Angela’s stuff I need to check all the pics

1. A sulfur atom contains 16 electrons.
a) how many electrons are in the first energy level? (1)
b) how many electrons are in the second energy level? (1)
c) how many electrons are in the third energy level? (1)
d) draw the electron configuration of this atom using planetary notation
 (3)
2. Define the following two terms:
	1. Valence electrons (1)
	2. Core electrons (1)
3. Refer to the atom pictured alongside.
a) of which element is this atom? (1)
d) how many energy levels does it have? (1)
c) how many valence electrons does it have? (1)
d) how many core electrons does it have? (1)
e) which element has the same electron configuration as this one’s core? (1)

2.35. I need to check pics

2.34 I need to check the picture.

1. Identify two differences between each of the following pairs:
	1. The potassium ion, K+ (2,8,8) and an argon atom, Ar (2,8,8) (2)
	2. The fluoride ion, F- (2,8) and the neon atom, Ne (2,8) (2)
2. Refer to the pictures alongside.
a) Which one is an ion: (i) or (ii)? (1)
b) What is the ion’s net charge? (1)
c) For (i) to change into (ii), what would have to happen? (1)
3. What kind of bonding would you expect to form between the following pairs of elements? Explain your decision.
	1. K and Cl
	2. Ca and O
	3. C and O
	4. P and I
	5. Mg and S

 (5)

1. Solid iodine forms deep purple/black crystals. Iodine vapourises to form a purple gas. Explain the difference in bonding between gaseous and solid iodine. (3)
2. Name the following compounds:
	1. Ag Br
	2. SO2
	3. PbO2
	4. Cu(SO4)2  (4)
3. Write the formulae for the following compounds:
	1. Carbon monoxide
	2. Calcium hydroxide
	3. Lithium nitrate
	4. Potassium sulfide (4)

Exchange this with the red stuff above

Answer the following questions on your own.

1. For each of the following, say what type of bond is pictured. (4)



1. Give the name of each of the following compounds:

a) K2SO4b) MgSO3
c) FeS
d) Na2CO3e) NH4Cl (10)

1. Choose the formula of each of the following compounds from the options given:
2. a) Lithium chloride (LiCl / Li2Cl / LiCl2)
b) Magnesium chloride (MgCl / Mg2Cl / MgCl2)
c) Lithium hydroxide (LiOH / Li2OH / Li(OH)2)
d) Magnesium hydroxide (MgOH / Mg2OH / Mg(OH)2)
e) Potassium nitrate (KNO3 / KNO2 / KN) (10)
3. Give the formula of each of the following:
a) Lithium oxide
b) Aluminium hydroxide
c) Potassium nitrite
d) Hydrogen sulphide
e) Copper(II) sulphate (10)
4. In a covalent bond, unpaired electrons are shared as their orbitals overlap.
i) Which of the following best represents the covalent bonds of H2O (water)?

**[insert A/W – im not sure]** (2)
ii) Which of the following best represents the covalent bond of Cl2?**[insert A/W]** (2)

7.Read the information below and then answer the questions that follow. (which info? Including did you know?

**[different font]**

Water (H2O) freezes when cooled to 0°C, forming ice. Carbon dioxide (CO2) freezes when cooled to -80°C, forming ‘dry ice’.
Ice melts when heated (H2O(s) → H2O(l)). Dry ice sublimes when heated (changes from solid to gas, i.e. CO2(s) → CO2(g)).
**[end font]**

**[icon]** Did you know? [should this be here?]

Because dry ice doesn’t ever turn into a liquid it is referred to as ‘dry’. It is often used in ice-cream carts because it keeps the ice-cream much cooler than water ice would, and it doesn’t melt and so make things soggy. Dry ice is often used in plays and films. When it is heated it changes to gas, cooling and condensing the air it moves through, forming mist.

a) For CO2(s) to become CO2(g), intermolecular bonds are broken. Which picture shows this? **[insert A/W]** (2)

b) CO2(s) is denser than CO2(g).
i) How would 2g CO2(s) and 2g CO2(g) differ because the solid form is
denser than the gaseous form? (2)
ii) Explain the difference in density by referring to intermolecular bond

strengths. (2)

c) CO2(s) particles are very cold (-80°C or less). CO2(g) particles are warmer.
 Explain this difference in temperature by referring to the speed, and
 therefore kinetic energy, of the particles. (2)

d) CO2(s) changes to CO2(g) at -80°C, as intermolecular bonds are broken.
H2O(s) changes to H2O(l) at 0°C, and H2O(l) changes to H2O(g) at 100°C, as intermolecular bonds are loosened and then broken. What do you conclude from this (choose the correct option):
A intermolecular bonds between CO2 molecules are stronger than those
 between H2O molecules

B intermolecular bonds between H2O molecules are stronger than those
 between CO2 molecules (2)

A useful diagram to summarise the different types of particles and their structures may look like this:

|  |  |  |  |
| --- | --- | --- | --- |
| Particles |  | Structures |  |
|  |  | Molecules | (found in solids, liquids and gases) |
| Atoms |  |  |  |
| ↓↑ |  | Giant structures | (found only in substances which are solid at room temperature) |
| Ions |  |  |  |
|  |  | Free ions | (found in solutions and molten substances) |

[why is this here? ] This is for the teacher’s book I guess

Total: 48

**[Icon]** Check yourselves

Swop your work with a partner and give each other a mark out on 48. Rate your performance using the following 6-point rating scale.

Insert 6-point rating scale

Insert reflection