1

Chemical naming

GOALS

1. Name and formulate covalent compounds
2. Name and formulate ionic compounds
3. Name and formulate acids and bases
4. Name and formulate oxosalts and common chemicals

ALL elements in the periodic table with the exception of the noble gases–He, Ne, Ar, Kr, Xe and Rn–combine to produce chemical compounds. Most of these chemicals are useful in your every day life, and you drink water to quench your thirst, use Clorox to clean your house or baking soda to get rid of a stinky refrigerator. In this chapter you will learn not only how to name these chemicals but also to read chemical formulas–we call this to formulate chemicals. Still, chemical elements such as hydrogen and oxygen do not combine randomly and they only choose specific elemental partners to form a compound. As an example, hydrogen combines with oxygen using specific proportions to produce H_2O and not HO_2. In this chapter you will also learn the rules that chemical elements use to combine.

1.1 Ions & ionic charges

Atoms gain and loose electrons to produce ions. An ion is just an atom with a positive or negative charge. Ions result from an electron transfer. Positive ions have lost negatively charged electrons, whereas negative ions have gained electrons. The reason for this electron transfer is that atoms try to achieve a very stable electronic configuration with eight electrons in the valence, and this is called the octet electron configuration. Examples of ions are: H^+, Ca^{2+} or O^{2-}. This section covers the properties of ions and the ionic charges.

Discussion: think about your household and the chemicals you use at home. List three chemicals you found around you, with its correct chemical name

`Cations and anions` Atoms that loose electrons become positively charged. These ions are called cations. Example of cations are Li^+ or Mg^{2+} called lithium cation and magnesium cation, respectively. Atoms that gain electrons become negatively charged, as electrons have negative charge. These ions are called anions. Example of anions are F^- called fluoride or N^{3-} called nitride. The way to name anions is by using the name of the element and the suffix -ide.

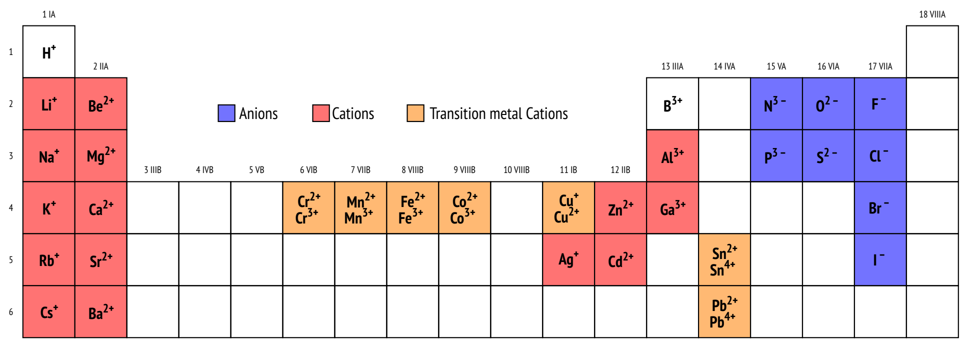

Figure 1.1 Ionic charges (valences) for different elements

Ionic charges: the valences How do we know that hydrogen produces a H^+ ion and nitrogen a N^{3-} anion. The charge of an ion is called ionic charges, and the numbers are coming from the periodic table. H, Na or K are in the group IA (left of the table) and hence the ionic charge will be $1+$. Similarly, Mg or Ca are in the group IIA (left of the table) and hence the ionic charge will be $2+$. Differently, F, Cl or Br are in the group 7A (right of the table) and its charge will be $1-$. Oxygen is in group 6A (right of the table) and the ionic charge will be $2-$. Figure 1.1 contains all ionic charges. What if the element is not in this list such as the case of Iron (Fe)? In that case, very probably it will have several ionic charges and this charge has to be indicated in the chemical name. An example would be Fe, which ionic charge is not in Figure **??** as iron can have several ionic charges.

Sample Problem 1

Identify the correct ionic state of: Cl, K, O and C.

SOLUTION

Cl is on the 7A group and hence its charge is $1-$, whereas potassium belongs to 1A and its charge will be $1+$. Oxygen and carbon will have $2-$ and $4-$ charges. The final ionic states are: Cl^-, K^+, O^{2-} and C^{4-}.

STUDY CHECK

Identify the correct ionic state of: N and Br.

1.2 Ionic compounds

Ionic compounds are chemicals resulting from the combination of a nonmetallic element with a metallic element. And example is NaCl, which results of combining sodium (a metal) with chloride (a non metal).

Combining ions Ionic compounds are the result of combining two ions: a positive (cation) and a negative (anion) ions. Each ion has a charge, depending on its location on the table. When combining two atoms you first need to arrange the ions starting from positive and followed by negative. The charges of an ion would become the coefficient of the other ion. For example Mg^{2+} and N^{3-} are combined as Mg_3N_2:

$$3Mg^{2+} \qquad 2N^{3-} \longrightarrow Mg_3N_2$$

Another example would be the combination of Na^+ and O^{2-} that would be Na_2O. You need to simplify the indexes of the formula by diving by the smallest one, always using integer values. For example, Mg^{2+} and O^{2-} give Mg_2O_2 that should be written as MgO

$$Mg^{2+} \qquad O^{2-} \longrightarrow Mg_{\cancel{2}}O_{\cancel{2}} \longrightarrow MgO$$

Another example that involves simplifying the formula is the chemical resulting of combining Ca^{2+} and C^{4-}. After combining the charges we obtain Ca_4C_2 that needs to be simplified dividing by the smallest number leading to Ca_2C.

Sample Problem 2

Combine the following ions or give the ions given the final compound:

Ions	Combination
Li^+ and O^{2-}	
Ca^{2+} and O^{2-}	
	Li_3N
	Mg_2C

SOLUTION

The result of combining Li^+ and O^{2-} is Li_2O. For Ca^{2+} and O^{2-}, the resulting chemical is CaO. Li_3N results from the combination of Li^+ and N^{3-}, and Mg_2C results from Mg^{2+} and C^{4-}.

STUDY CHECK

Combine the following ions or give the ions given the final compound: Na^+ and F^- and Na_3N.

Simple ionic naming (type I ionic) Type I ionic compounds result from the combination of a metal with given valence (Li, Ca, Mg, etc.) and a non metal. In order to name an ionic compound (type I ionic) you need to (a) use the name of the first element in the compound, (b) use the first syllable of the second element, and (c) finish the name of the molecule in the suffix *-ide*. As an example, the formula NaCl is named as sodium chloride and $MgCl_2$ is named magnesium chloride. Another example would be:

$CaCl_2$	calcium chloride	LiO_2	lithium oxide

In order to formulate an ionic compound based on a name, we need to combine both ions by exchanging the valences (the ionic charges). For example,$MgCl_2$ results of the combination of Mg^{2+} and Cl^- so that the number 2 in $MgCl_2$ near the Cl atom is coming from the Mg^{2+}. In other words:

$$Mg^{2+} + 2Cl^- \longrightarrow MgCl_2$$

The sign of the charges only indicate which element goes first in the formula: the positive element (cation) first following by the negative element (anion). For example the result of combining Na^+ and Cl^- is NaCl and not ClNa as Na has positive ionic charge and has to appear first in the formula.

Sample Problem 3

Name or give the formula for the following ionic compounds:

Formula	Name
MgO	
Mg_3N_2	
	Lithium nitride
	Magnesium carbide

SOLUTION

The name for MgO is magnesium oxide. Mg_3N_2 is called magnesium nitride. The formula for Lithium nitride is Li_3N and the formula for Magnesium carbide is Mg_2C, result of simplifying Mg_4C_2 dividing by two, the smallest number.

STUDY CHECK

Name or give the formula for the following ionic compounds: Sodium fluoride and Na_3N.

Complex ionic naming The ionic chemical NaCl results from the combination of Na^+ and Cl^-. The ionic charges of Na and Cl are given in Figure **??** according to the group. If the ionic chemical contains a transition metal with variable ionic charge, that is, which is not in Figure **??** then the ionic naming becomes a bit more complex. The reason is that one needs to specify the charge of the metal, explicitly in the name of the chemical. An example would be $NiCl_2$ named as Nickel(II) chloride or Co_2O_3 named as Cobalt(III) oxide.

Name complex ionic chemicals This section covers how to name ionic chemicals containing a metal with variable charge. In this case you need to specify the charge of the metal in the name. In order to calculate this number you will solve a simple math equation. For example, the name of Mn_2O_3 is Manganese(III) oxide. How do we get this name? Manganese has several charges as it is not in Figure **??**, lets use x for its charge Mn^x and oxygen has a charge of two O^{2-}. After combining Mn^x and O^{2-} the resulting formula would be Mn_2Ox. By comparison with the given formula, Mn_2O_3 , x has to be three and hence the charge of Mn has to be three. Therefore, the final name would be Manganese(III) oxide.

Properties of ionic compounds Ionic compounds normally have high melting points and are solid at normal conditions. An typical ionic compound would be NaCl, cooking salt.

The ionic bond Atoms of an ionic compound are connected by means of an ionic bond. In an ionic bond, one element gives away electrons (the cation) and the other one receives electrons (the anion). As an example, in the NaCl molecule Na gives away an electron to Cl and the molecule results from the combinations of Na^+ and Cl^+. In an ionic compound the element on the left is positive and the one on the right is negative.

Sample Problem 4

Name or give the formula for the following ionic compounds:

Formula	Name
MnO	
Fe_3N_2	
	Cobalt(II) carbide
	Iron(II) oxide

SOLUTION

All the chemicals on this example contain a metal that can have several charges, and hence, we need to specify the ionic charge on the name. MnO results from Mn^x and O^{2-}. After combining the ions, the formula would be Mn_2Ox, a formula that needs to be compared to MnO. The formulas do not look similar, so lets make them more similar by dividing by two so that $MnO_{\frac{x}{2}}$ resembles MnO. By comparing x has to be 2 and hence the name is Manganese(II) oxide. The name for Fe_3N_2 would be Iron(II) nitride. The valence of Iron comes from combining Fe^x and N^{3-} that gives Fe_3Nx. By comparison with Fe_3N_2 x has to be two and the name is Iron(II) nitride. the formula for Cobalt(II) carbide would be Co_2C as Cobalt(II) is Co^{2+} and carbide is C^{4-}. After combining the ions one obtains Co_4C_2 that gives Co_2C. Finally, the formula for Iron(II) oxide is FeO as Iron(II) is Fe^{2+} and oxide is O^{2-} that gives Fe_2O_2 and simplifying one obtains FeO.

STUDY CHECK

Name or give the formula for the following ionic compounds: Manganese(IV) oxide and AuCl.

1.3 Covalent compounds

Covalent compounds are chemicals resulting from the combination of nonmetallic elements. And example is CO_2, which results of combining carbon (a non metal) with oxygen (a non metal).

Covalent naming In order to name a covalent compound you need to (a) use the name of the first element in the compound, (b) use the first syllable of the second element, and (c) finish the name of the molecule in the suffix *-ide*. More importantly, you need to use prefixes that indicate the number of atoms in the molecule. See Table 1 for a list of the different equivalencies between prefixes and number. As an example, the formula CH_4 is named as carbon tetrahydride. Similarly, a covalent chemical name can be translated into a formula (we call this to formulate a chemical with a given name), and the formula for carbon monoxide would be CO. When the vowels *a* and *o* appear together, the first vowel is omitted as in carbon monoxide instead of carbon ~~monooxide~~. Another example would be N_2O named as dinitrogen oxide, and the name sulfur hexafluoride corresponds to the formula SF_6. The prefix mono is omitted in the first element of the name, and for example you will not name the chemical CO as ~~monocarbon~~ monoxide, you would just say carbon monoxide. A final example of a covalent compound:

N_2O_5	dinitrogen pentoxide	BCl_3	Boron trichloride

Table 1.1 Prefixes used to name covalent compounds

Prefix	number	Prefix	number
Mono	1	Hexa	6
Di	2	Hepta	7
Tri	3	Octa	8
Tetra	4	Nona	9
Penta	5	Deca	10

Sample Problem 5

Name of give the name of the following covalent chemicals:

Formula	**Name**
NO	
CS_2	
	Sulfur Dioxide
	Nitrogen Trichloride

SOLUTION

All chemicals in this example are covalent as they result of the combination of nonmetals. In order to name them, we need to use prefixes and finish the sufix with -ide. The first chemical is called nitrogen oxide. CS_2 is called carbon disulfide. The formula for sulfur dioxide and nitrogen trichoride are respectively SO_2 and NCl_3.

STUDY CHECK

Name of give the name of the following covalent chemicals: SCl_2 and diboron thrioxide.

`Properties of covalent compounds` At normal conditions, covalent compounds may exist as solids, liquids, or gases. Covalent compounds do not exhibit any electrical conductivity, either in pure form or when dissolved in water. A typical covalent compound would be H_2O, water.

`The covalent bond` Atoms in a covalent compound are connected by means of a covalent chemical bond. In a covalent bond, both atoms connected share the electrons. As an example, the HCl molecule has an hydrogen and a chlorine atom connected by means of a covalent bond, in which each atoms share the electrons of the bond.

1.4 Naming acids & bases

In this section we will learn how to name acids and bases. Acids normally have common names (e.g. sulfuric acid) and its naming does not follow modern rules. Names and formulas of acids are listed in tables. Differently, bases (e.g. sodium hydroxide) are named in a standard way.

`Bases or hydroxides` Bases (hydroxides) result from the combination of a metal and the hydroxide anion (OH^-). Examples are NaOH or $Ca(OH)_2$. The name of a base starts by the name of the cation finishing by the word *hydroxide*. An example is NaOH named as *sodium hydroxide*, or $Ca(OH)_2$, named as *calcium hydroxide*. The word *hydroxide* refers to the OH^- ion, and hence Sodium hydroxide results from combining Na^+ and OH^-, and Calcium hydroxide from combining Ca^{2+} and OH^-. More examples of hydroxides:

$Mg(OH)_2$	Magnesium hydroxide

Acids Acids–in particular inorganic acids–are chemicals that normally contain hydrogen at the beginning of its formula. For example, HCl or H_2SO_4. HCl is an hydracid and is named as *hydrochloric acid*, whereas H_2SO_4 is an oxoacid that contains oxygen named as *sulfuric acid*. The names of acids are not standard and they come from common names employed in the field for many years. Table 1.1 contains a list of the most important oxoacids and hydracids. More examples of acids:

HNO_3	Nitric acid	HF	Hydrofluoric acid

Sample Problem 6

Name or give the formula for the following acids and bases. Indicate whether the compound is an acid or a base.

Formula	Acid/Base	Name
HCN		
KOH		
		Carbonic acid
		Lithium hydroxide

SOLUTION

HCN is an acid named hydrocyanic acid. KOH is a base called potassium hydroxide. The formula for Carbonic acid is H_2CO_3, and Lithium hydroxide is a base with formula LiOH.

STUDY CHECK

Name or give the formula for the following ionic compounds: phosphoric acid and $Mg(OH)_2$.

Oxidation states of oxoacids Consider the following set of acids: HClO, $HClO_2$, $HClO_3$ and $HClO_4$. We say Cl in these acids have different oxidation state or different oxidation number. This section will cover the calculation of the oxidation state of the central atom of an oxoacid.

Let us address the oxoacid: $H\underline{Cl}O_3$. The goal is to calculate the oxidation number of the underline element, Cl. In order to do this we will follow a set of simple rules. First, we will use the valences as the oxidation number of the elements to the right and to the left of the central atom. Then, we will assign an unknown oxidation state of x to the central atom. After that we will set up a equation so that the sum of all oxidation numbers equals to the charge of the acid, if any. In this formula, we will include the atomic coefficients. In the case of $H\underline{Cl}O_3$, the equation would be:

$$1 + x + 3 \cdot (-2) = 0$$

as the number of oxygens is three, we will have to time by three the valence of oxygen. The number zero results from the charge of the acid. If we solve for x, we obtain: $x = 5$. That is, the oxidation state of Cl on $H\underline{Cl}O_3$ is 5 and this is represented as$H\underline{Cl^{V}}O_3$.

`Oxidizing and reducing character of oxoacids` The importance of the oxidation state of the central elements of an oxoacid results from the fact that acids with high or low oxidation states, tends to be very reactive, being sometimes capable of completely dissolving metals. We call these oxidizing (or reducing) acids. For example, HNO_3 and H_2SO_4 and both oxidizing acids and these acids will solve for example a piece of copper. Similarly, acids with very small or negative oxidation numbers can be very reactive as well. These acids are called reducing acid sor agents. Let us compare two oxoacids in order to elaborate more on the terminology used to describe redox numbers. For example, let us compare $H\underline{Cl^{V}}O_3$ and $H\underline{Cl^{III}}O_2$. We say Cl on $H\underline{Cl^{V}}O_3$ has a larger redox number than $H\underline{Cl^{III}}O_2$. We can also say, Cl in $H\underline{Cl^{V}}O_3$ is more oxidized than Cl on $H\underline{Cl^{III}}O_2$. Finally, we can also say, $H\underline{Cl^{V}}O_3$ is more reducing than $H\underline{Cl^{III}}O_2$. Again, the terms associated with high redox numbers are oxidized and reducing, and the terms associated with low redox numbers are reduced and oxidizing.

It is important to note that ultimately the oxidation state of an element is related to the number of electrons of the element. The more electrons the smaller–the more negative–the oxidation state. In other words, large oxidation states result from losing electrons.

Sample Problem 7

Calculate the redox number of S in the following acids and indicate the more oxidizing acid: $H_2\underline{S}_2O_6$ named dithionic acid and $H_2\underline{S}O_4$ named sulfuric acid.

SOLUTION

We will set up the redox formula for the first acid ($H_2\underline{S}_2O_6$), given that the redox number of H is $+1$ and the redox number of O is -2.

$$2 \cdot 1 + 2 \cdot x + 6 \cdot (-2) = 0$$

Solving for x:

$$2 + 2 \cdot x - 12 = 0 \quad \text{we have that } x = \frac{12 - 2}{2}$$

The oxidation state of S in $H_2\underline{S}_2O_3$ is $+5$. For the second acid ($H_2\underline{S}O_4$):

$$2 \cdot 1 + x + 4 \cdot (-2) = 0$$

Solving for x:

$$2 + x - 8 = 0 \quad \text{we have that } x = \frac{8 - 2}{1}$$

that gives a redox of 6. If we compare both acids the smaller the redox number the more reduced is the central element and the more oxidizing the acid is. Therefore, $H_2\underline{S}_2O_3$ is more oxidizing than $H_2\underline{S}O_4$.

STUDY CHECK

Calculate the redox number of the following acids: H_2MnO_4 and $H_2Cr_2O_7$.

Table 1.2 Names of oxoacids and oxosalts (top table) and hyracids (bottom table). Yellow rows need to be remembered.

Element	Oxoacid	Oxoacid Name	Oxoasalt	Oxoasalt Name
Manganese	$HMnO_4$	Permanganic Acid	$MnO_4{}^{-}$	Permanganate
	H_2MnO_4	Manganic acid	$MnO_4{}^{-2}$	Manganate
Carbon	H_2CO_3	Carbonic Acid	$CO_3{}^{-2}$	Carbonate
Nitrogen	HNO_3	Nitric Acid	$NO_3{}^{-}$	Nitrate
	HNO_2	Nitrous Acid	$NO_2{}^{-}$	Nitrite
Phosphorus	H_3PO_4	Phosphoric Acid	$PO_4{}^{-3}$	Phosphate
Sulfur	H_2SO_4	Sulfuric Acid	$SO_4{}^{-2}$	Sulfate
	H_2SO_3	Sulfurous Acid	$SO_3{}^{-2}$	Sulfite
	$H_2S_2O_2$	Thiosulfurous Acid	$S_2O_2{}^{-2}$	Thiosulfite
	$H_2S_2O_3$	Thiosulfuric Acid	$S_2O_3{}^{-2}$	Thiosulfate
	$H_2S_2O_7$	Disulfuric acid	$S_2O_7{}^{-2}$	Disulfate
	$H_2S_2O_8$	Peroxodisulfuric acid	$S_2O_8{}^{-2}$	Peroxodisulfate
Chlorine	$HClO_4$	Perchloric Acid	$ClO_4{}^{-}$	Perchlorate
	$HClO_3$	Chloric acid	$ClO_3{}^{-}$	Chlorate
	$HClO_2$	Chlorous acid	$ClO_2{}^{-}$	Chlorite
	$HClO$	Hypochlorous acid	ClO^{-}	Hypochlorite
Iodine	HIO_4	Periodic Acid	$IO_4{}^{-}$	Periodate
Chromium	H_2CrO_4	Chromic acid	$CrO_4{}^{2-}$	Chromate
	$H_2Cr_2O_7$	Dichromic acid	$Cr_2O_7{}^{2-}$	Dichromate
Boron	H_3BO_3	Boric acid	$BO_3{}^{3-}$	Borate

Hydracid	Hydracid Name	Hydracid	Hydracid Name
HCl	Hydrochloric acid	HBr	Hydrobromic acid
HI	Hydroiodic acid	HF	Hydrofluoric acid
HCN	Hydrocyanic acid	H_2S	Hydrosulfuric acid

1.5 Naming complex salts & common chemicals

At this point we saw the naming and formulation of ionic (e.g. NaCl) and covalent compounds (e.g. CO_2). This section covers the naming of complex salts: oxosalts and hydrosalts. In general, salts (oxosalts or hydrosalts) are the result of mixing an oxoacid and a base. They tend to look more complex than simple ionic or covalent compounds as they have at least three different elements. An example of oxosalt would be $CaSO_4$ called calcium carbonate. An example of hydrosalt would be $NaHSO_4$ which is called sodium monohydrosulfate. This section will also cover the naming of hydrates (e.g. $CaSO_4 \cdot H_2O$), that are compounds containing water molecules inside its structure. Before being able to name these complex chemicals it is convenient to practice combining ions, without paying attention to the naming.

`Combining ions` In order to combine two ions, you first arrange the positive ion in the left followed by the negative ion in the right, to then cross the ionic charges from the top of the ion to the bottom of the opposite ion. The positive and negative charges are not carried. If the ions have more than one element we have to use parenthesis. An example would be combining Ca^{2+} and $PO_4{}^{3-}$ leading to $Ca_3(PO_4)_2$:

$$3Ca^{2+} + 2PO_4^{3-} \longrightarrow Ca_3(PO_4)_2$$

We would simplify in case the charges compensate with each other.

An example would be combining Mg^{2+} and $SO_4{}^{2-}$ leading to $MgSO_4$

$$Mg^{2+} \quad SO_4^{2-} \longrightarrow Mg_{\cancel{2}}(SO_4)_{\cancel{2}} \longrightarrow MgSO_4$$

Naming Oxosalts The names of the oxosalts are constructed by combining the name of the first element–you need to specify its charge in the case of a transition metal element with different possible charges–followed by the name of the oxosalt from Table 1.2. For example, the name of $MgSO_4$ is magnesium sulfate, as Mg^{2+} is magnesium and $SO_4{}^{2-}$ is sulfate. Another example is$Fe_2(CO_3)_3$ called Iron(III) carbonate. A final example:

$NO_3{}^-$	Nitrate	$LiNO_3$	Litium nitrate (oxosalt)

Formulating Oxosalts In the case that you know the name of an oxosalt and you want to obtain its formula, you first need to arrange the positive ion in the left followed by the negative ion in the right, to then cross the ionic charges from the top of the ion to the bottom of the opposite ion. For example, calcium nitrate results from the combination of Ca^{2+} calcium and $NO_3{}^-$, nitrate. By combining the two ions we obtain the final formula as $Ca(NO_3)_2$:

$$Ca^{2+} \quad NO_3^{-} \longrightarrow Ca(NO_3)_2$$

Sample Problem 8

Name of give the name of the following oxosalts:

Formula	Name
K_2SO_4	
Na_2CO_3	
	Magnesium carbonate
	Sodium phosphate

SOLUTION

K_2SO_4 is named potassium sulfate, as K^+ is potassium and $SO_4{}^{2-}$ stands for sulfate. Na_2CO_3 is sodium carbonate. Magnesium carbonate is $MgCO_3$ and sodium phosphate is Na_3PO_4.

STUDY CHECK

Name of give the name of the following oxosalts: $CaSO_4$ and Aluminum sulfate.

Naming Hydrosalts Hydrosalts are related to oxosalts (e.g. Na_2SO_4) and they resemble these chemicals while having hydrogen atoms in their chemical formula, in between the oxosalt cation and anion (e.g. $NaHSO_4$). That is the reason they are called hydrosalts as they are oxosalts with hydrogen. For example, $NaHSO_4$ is named sodium monohydrogensulfate. In order to understand this name, we will first focus on the second part on the name, monohydrogensulfate that represents the hydrosalt anion. The name monohydrogensulfate (HSO_4^-) comes from adding a proton (H^+) to a sulfate cation (SO_4^{2-}). Mind that protons (H^+) are positively charged and therefore if we add a single H^+ to a sulfate cation (SO_4^{2-}) the charge will have to decrease a single unit, giving us HSO_4^-. As we can see, the name of hydrosalt anions are directly related to the oxosalt anion and the number of hydrogens in the hydrosalt name. For example, phosphate (PO_4^{3-}) is an oxosalt anion whereas hydrogenphosphate (HPO_4^{2-}) and dihydrogenphosphate ($H_2PO_4^-$) are both hydrosalt anions. An explanation about the charges: as phosphate has three negative charges, hydrogenphosphate has to have one less charge (that is 2−) and dihydrogenphosphate hast to have two less negative charges (that is −1). Some final hydrosalt anions examples:

CO_3^{-2}	carbonate (oxosalt)	HCO_3^-	monohydrogen carbonate (hydrosalt)
BO_3^{-3}	borate (oxosalt)	$H_2BO_3^-$	dihydrogen borate (hydrosalt)

Above we saw how to name just the ending of the hydrosalt. Now we can move forward to the naming of hyrdrosalts. We just need to add the name of the element in the first place, and for example NaH_2BO_3 would be named sodium dihydrogenborate. If the first ion–the cation–is a transition metal cation (a type two cation) we need to include in parenthesis the valence of the cation. For example, $Fe(H_2BO_3)_2$ would be named iron(II) dihydrogenborate. More examples:

Na_2CO_3	sodium carbonate	$NaHCO_3$	sodium monohydrogen carbonate (hydrosalt)

Sample Problem 9

Name or formulate the following hydrosalts:

Formula	Name
	Magnesium hydrogensulfate
	Sodium hydrogen carbonate
$LiHCO_3$	
MgH_2PO_4	

SOLUTION

The formula of Magnesium hydrogensulfate is $Mg(HSO_4)_2$ as the formula for monohydrogen sulfate is HSO_4^- and the valence of magnesium is Mg^{2+}. The formula for Sodium monohydrogen carbonate is $NaHCO_3$ as it results from combining Na^+ and HCO_3^-. Mind monohydrogen carbonate results from adding a hydrogen ion H^+ to a carbonate CO_3^{2-} ion. The name for $LiHCO_3$ is lithium monohydrogen carbonate, whereas the name for MgH_2PO_4 is magnesium dihydrogenphosphate.

STUDY CHECK

Name or formulate the following hydrogensalts: $LiHS_2O_3$, LiH_2PO_4 and sodium hydrogenphosphate.

`Hydrates` Some chemicals contain water molecules trapped in its structure and therefore water molecules (H_2O) are often indicated in chemical formulas. These types of chemicals containing water are called *hydrates*, precisely because hydrate means water. Examples of hydrates are: $BeSO_4 \cdot 4\,H_2O$ or $CuSO_4 \cdot 5\,H_2O$ called respectively beryllium sulfate tetrahydrate and cupper(II) sulfate pentahydrate. In order to formulate hydrates you just need to use prefixes such as mono, di, tetra–the same ones we use to name covalent chemicals–to indicate the number of water molecules in the chemical and end the name with *hydrate*. As a note, warming up hydrates (e.g. $BeSO_4 \cdot 4\,H_2O$) results on the release of water producing a dehydrated or *anhydrous* compound (e.g. $BeSO_4$). A final example of hydrate naming:

$Na_2SO_4 \cdot 5\,H_2O$	(a hydrate)	Sodium sulfate pentahydrate

Sample Problem 10

Name or formulate the following hydrates:

Formula	Name
	Nickel(II) permanganate dihydrate
	Sodium nitrate monohydrate
$Na_2CO_3 \cdot 10\,H_2O$	
$MgSO_4 \cdot 7\,H_2O$	

SOLUTION

The formula for Nickel(II) permanganate is $Ni(MnO_4)_2$, therefore the formula for Nickel(II) permanganate dihydrate is $Ni(MnO_4)_2 \cdot 2\,H_2O$. The formula for Sodium nitrate is $NaNO_3$, therefore $NaNO_3 \cdot H_2O$ is Sodium nitrate monohydrate. The name for $Na_2CO_3 \cdot 10\,H_2O$ is sodium carbonate decahydrate and $MgSO_4 \cdot 7\,H_2O$ is magnesium sulfate heptahydrate.

STUDY CHECK

Name or formulate the following hydrates: $LiNO_3 \cdot H_2O$, $Na_3PO_4 \cdot 3\,H_2O$ and sodium sulfate tetrahydrate.

`Common naming` Some of the chemicals are normally referred by a common name that does not involve the use of any chemical naming rules. An example would be H_2O normally referred as water instead of its standard name that is dihydrogen oxide. You can find more names in Table 1.2. Another example:

NaCl	Sodium chloride (standard name)	Table salt (common name)

Table 1.3 List of common chemicals

Chemical	Name	Chemical	Name
H_2O	Water	$Mg(OH)_2$	Milk of magnesia
NH_3	Ammonia	N_2O	Laughing gas
CH_4	Methane	$CaCO_3$	Marble
CO_2	Dry ice	CaO	Quicklime
$NaCl$	Table salt	$NaHCO_3$	Baking Soda
$NaHCO_3$	Sodium Bicarbonate	$MgSO_4 \cdot 7\,H_2O$	Epsom Salt

Sample Problem 11

Name or formulate the following common chemicals: milk of magnesia and dry ice.

SOLUTION

The formula for milk of magnesia is $Mg(OH)_2$ (magnesium hydroxide), whereas dry ice is the common name for CO_2, carbon dioxide.

STUDY CHECK

Name or formulate the following common chemicals: ammonia and methane.

CHAPTER 1

Ions & Ionic charges

1.1 Indicate if the following chemical species represent an atom, and anion or a cation: (a) Fe^{2+} (b) Cl^- (c) Ag

1.2 Identify the ionic state of the following elements. If needed, indicate the existence of multiple ionic states: (a) H (b) O (c) N (d) F (e) Mn

1.3 Identify the ionic state of the following elements. If needed, indicate the existence of multiple ionic states: (a) Li (b) V (c) Cl (d) S (e) Cr (f) Sr (g) Ni

Covalent compounds

1.4 Name or formulate the following covalent compounds: (a) NO (b) Dichlorine monofluoride (c) NO_2

1.5 Name or formulate the following covalent compounds: (a) Chlorine Monofluoride (b) N_2O (c) Nitrogen trifluoride

1.6 Name or formulate the following covalent compounds: (a) SO_3 (b) Disulfur dichloride (c) SO_2 (d) Disulfur tetrachloride

1.7 Name or formulate the following covalent compounds: (a) P_4S_3 (b) Sulfur Tetrafluoride (c) As_2O_5 (d) Sulfur trioxide

Ionic compounds

1.8 Classify the following chemicals in two groups, justifying your classification: (a) NaCl (b) CO_2 (c) $FeCl_3$ (d) N_2O_3(e) SO_3(f) Ca_3N_2

1.9 Combine the following ions:

(a) $Na^+ + Cl^-$
(b) $Na^+ + Se^{2-}$
(c) $Na^+ + P^{3-}$
(d) $Mg^{2+} + Cl^-$
(e) $Mg^{2+} + O^{2-}$
(f) $Mg^{2+} + N^{3-}$

1.10 Name or formulate the following ionic (Type I) compounds: (a) Magnesium iodide(b) Ca_3P_2 (c) Lithium nitride(d) MgF

1.11 Name or formulate the following ionic (Type I) compounds: (a) Magnesium fluoride(b) CaS (c) Barium phosphide(d) Mg_3N_2

1.12 Name the following compounds:

(a) NaCl
(b) Ca_3N_2
(c) MgI_2
(d) SrS
(e) RbCl
(f) KF

1.13 Combine the following ions:

(a) $Cs^+ + Ni^-$
(b) $Sr^{2+} + Mn^{2-}$
(c) $Be^{2+} + Co^{4-}$
(d) $Li^+ + Cu^-$
(e) $Mg^{2+} + Cr^{-6}$

1.14 Classify the following chemicals in two groups. Justify your classification.

(a) NaCl
(b) MnO_2
(c) $FeCl_3$
(d) SrO
(e) Li_3N
(f) NiO

1.15 Formulate the following compounds:

(a) Copper(I) oxide
(b) Copper(II) nitride
(c) Nickel(III) oxide
(d) Manganese(IV) oxide

1.16 Name the following compounds:

(a) NiO
(b) Cr_2O_3
(c) VO
(d) MnO_4

1.17 Formulate the following compounds:

(a) Iron(II) nitride
(b) Copper(I) sulfide
(c) Chromium(III) iodide
(d) Palladium(IV) phosphide
(e) Manganese(VI) oxide

1.18 Name the following compounds:

(a) Ni_2O_3
(b) Fe_3N_2
(c) Cr_2O_3
(d) Ni_3P_2
(e) Ru_2Se_3

1.19 Name the following compounds:

(a) FeO
(b) CrN
(c) ZnI_2
(d) CoS
(e) MnF_3
(f) Cu_2C
(g) Ag_2O

1.20 Name or formulate the following ionic (Type II) compounds: (a) Fe_3P_2 (b) Copper(II) iodide (c) Fe_3N_2 (d) Iron(II) sulfide

1.21 Name or formulate the following ionic (Type II) compounds: (a) Fe_2S_3 (b) Gold(III) chloride (c) FeO (d) Vanadium(V) nitride

1.22 Name or formulate the following ionic (Type II) compounds: (a) FeI_2 (b) Lead(IV) sulfide (c) $FeBr_2$

1.23 Name or formulate the following ionic (Type II) compounds: (a) Manganese(IV) oxide (b) $FeCl_2$ (c) Copper(I) oxide

ACIDS AND HYDROXIDES

1.24 Name or formulate the following acids or bases: (a) HCl (b) Hydrofluoric Acid (c) $Mg(OH)_2$

1.25 Name or formulate the following acids or bases: (a) Sulfuric Acid (b) H_2CO_3 (c) Lithium hydroxide

1.26 From the following chemicals identify acids and bases: (a) KOH (b) $LiOH$ (c) CH_3OH

1.27 From the following chemicals identify acids and bases: (a) H_2SO_3 (b) NH_3 (c) $Ca(OH)_2$

1.28 From the following chemicals identify hydracids and oxoacids: (a) HF (b) H_2SO_3 (c) H_2S

1.29 From the following chemicals identify hydracids and oxoacids: (a) H_3BO_3 (b) HCl (c) HI

1.30 Memorize the following oxoacids:

(a) H_2SO_4 Sulfuric acid
(b) H_2CO_3 Carbonic acid
(c) $HMnO_4$ Permanganic acid
(d) HNO_3 Nitric acid
(e) H_3PO_4 Carbonic acid
(f) $H_2Cr_2O_7$ Dicromic acid

1.31 Identify the redox number of the central atom of the following oxoacids: (a) H_2CrO_4 (b) $H_2Cr_2O_7$ (c) $HMnO_4$

1.32 Identify the redox number of the central atom of the following oxoacids: (a) H_2MnO_4 (b) $HReO_3$ (c) H_2SiO_3

1.33 Identify the most oxidated acid:

(a) H_3AsO_4 or H_3AsO_3
(b) H_2XeO_4 or H_4XeO_6

1.34 Identify the most reduced acid:

(a) H_2RuO_4 or $HRuO_4$
(b) $HTcO_4$ or H_2TcO_4

1.35 Identify the most oxidant acid:

(a) $H_2S_2O_6$ or H_2SO_4
(b) H_2SeO_4 or H_2SeO_3

NAMING OF COMPLEX SALTS AND COMMON CHEMICALS

1.36 Name or formulate the following oxoanions:

(a) ClO_4^-
(b) PO_4^{3-}
(c) SO_4^{2-}
(d) CO_3^{2-}
(e) NO_3^-
(f) CrO_4^{2-}
(g) BO_3^{3-}

1.37 Name or formulate the following (Type I) oxosalts: (a) $Mg(NO_3)_2$ (b) Sodium permanganate (c) $KMnO_4$ (d) Calcium carbonate (e) Li_3PO_4

1.38 Name or formulate the following (Type I) oxosalts: (a) Lithium sulfate (b) Na_2CrO_4 (c) Lithium sulfite (d) $Cs_2Cr_2O_7$ (e) Calcium sulfate

1.39 Name or formulate the following compounds:

(a) Na_2SO_4
(b) KNO_3
(c) $CaCO_3$
(d) $Ca(NO_2)_2$
(e) $SrSO_3$

1.40 Combine the following ions:

(a) $Na^+ + PO_4^{3-}$
(b) $Li^+ + MnO_4^-$
(c) $Mg^{2+} + NO_3^-$
(d) $Ca^{2+} + CO_3^{2-}$
(e) $Cs^+ + Cr_2O_7^{2-}$
(f) $K^+ + BO_3^{3-}$

1.41 Combine the following polyatomic ions:

(a) $Na^+ + NO_3^-$
(b) $Na^+ + CO_3^{2-}$
(c) $Na^+ + PO_4^{3-}$
(d) $Ca^{2+} + CO_3^{2-}$
(e) $Ca^{2+} + PO_4^{3-}$

1.42 Name or formulate the following (Type II) oxosalts: (a) $Cr_2(SO_4)_3$ (b) zinc(II) carbonate (c) $Fe(MnO_4)_3$

1.43 Name or formulate the following (Type II) oxosalts: (a) cobalt(III) carbonate (b) $Fe(ClO_4)_3$ (c) zinc(II) carbonate

1.44 Name or formulate the following hydrosalts: (a) $NaHCO_3$ (b) Calcium Hydrogencarbonate (c) $Al(HSO_4)_3$

1.45 Name or formulate the following hydrosalts: (a) Sodium dihydrogenphosphate (b) LiH_2PO_4 (c) Silver monohydrogenphosphate

1.46 Name or formulate the following hydrates: (a) $Al_2(SO_4)_3 \cdot 3\,H_2O$ (b) Silver phosphate dihydrate (c) $KMnO_4 \cdot 4\,H_2O$ (d) Lithium sulfate tetrahydrate

1.47 Name or formulate the following compounds: (a) $MgSO_4$ (b) $Ni(SO_4)_3$ (c) Cobalt(II) nitrate (d) Cobalt(II) sulfate dihydrate (e) $KHCO_3$

1.48 Name or formulate the following compounds: (a) $Ca(NO_3)_2$ (b) $Na(HCO_3)_2$ (c) Nickel(II) sulfate (d) Nicke(II) sulfate tetrahydrate (e) NaH_2PO_4

1.49 Name or formulate the following compounds:

(a) $MnSO_4$
(b) $CuNO_3$
(c) $Cr_2(CO_3)_3$
(d) $V(NO_2)_2$
(e) $FeSO_3$

1.50 Name or formulate the following pairs or ions:

(a) carbonate and monohydrogencarbonate
(b) sulfate and monohydrogensulfate
(c) cromate and monohydrogenchromate
(d) phosphate and dihydrogenphosphate
(e) phosphate and monohydrogenphosphate
(f) borate and dihydrogenphosborate

Answers **1.1** (a) Fe^{2+} (cation) (b) Cl^- (anion) (c) Ag (atom) **1.3** (a) Li Li^+ (b) V (multiple) (c) Cl Cl^- (d) S S^{2-} (e) Cr (multiple) (f) Sr Sr^{2+} (g) Ni (multiple) **1.5** (a) Chlorine Monofluoride (ClF) (b) N_2O (dinitrogen monoxide) (c) Nitrogen trifluoride(NF_3) **1.7** (a) P_4S_3 (tetraphosporus trisulfide) (b) Sulfur Tetrafluoride (SF4) (c) As_2O_5 (diarsenic pentoxide) (d) Sulfur trioxide (SO3) **1.9** (a) Na^+ + Cl^- (NaCl) (b) Na^+ + Se^{2-} (Na_2S) (c) Na^+ + P^{3-} (Na_3P) (d) Mg^{2+} + Cl^- ($MgCl_2$) (e) Mg^{2+} + O^{2-} (MgO) (f) Mg^{2+} + N^{3-} (Mg_3N_2) **1.11** (a) Magnesium fluoride (MgF_2) (b) CaS (Calcium sulfide) (c) Barium phosphide (Ba_3P_2) (d) Mg_3N_2 (magnesium nitride) **1.13** (a) Cs^+ + Ni^- (CsNi) (b) Sr^{2+} + Mn^{2-} (CrMn) (c) Be^{2+} + Co^{4-} (Be_2Co) (d) Li^+ + Cu^- (LiCu) (e) Mg^{2+} + Cr^{-6} (Mg_3Cr) **1.15** (a) Copper(I) oxide (Cu_2O) (b) Copper(II) nitride (Cu_3N_2) (c) Nickel(III) oxide (Ni_3O_2) (d) Manganese(IV) oxide (MnO_2) **1.17** (a) Iron(II) nitride (Fe_3N_2) (b) Copper(I) sulfide (Cu_2S) (c) Chromium(III) iodide (CrI_3) (d) Palladium(IV) phosphide (Pd_3P_4) (e) Manganese(VI) oxide (MnO_3) **1.19** (a) FeO (Iron(II) oxide) (b) CrN (Chromium(III) nitride) (c) ZnI_2 (Zinc iodide) (d) CoS (Cobalt(II) sulfide) (e) MnF_3 (Manganese(III) fluoride) (f) Cu_2C (copper(IV) carbide) (g) Ag_2O (silver oxide) **1.21** (a) Fe_2S_3 (Iron(III) sulfide) (b) Gold(III) chloride ($AuCl_3$) (c) FeO (Iron(II) oxide) (d) Vanadium(V) nitride (V_3N_5) **1.23** (a) Manganese(IV) oxide (MnO_2) (b) $FeCl_2$ (Iron(II) chloride) (c) Copper(I) oxide (Cu_2O) **1.25** (a) Sulfuric Acid (H_2SO_4) (b) H_2CO_3 (carbonic acid) (c) Lithium hydroxide (LiOH) **1.27** (a) H_2SO_3 (acid, inorganic) (b) NH_3 (base) (c) $Ca(OH)_2$ (base) **1.29** (a) H_3BO_3 (oxacid) (b) HCl (hydracid) (c) HI (hydracid) **1.31** (a) H_2CrO_4 redox=6 (b) $H_2Cr_2O_7$ redox=6 (c) $HMnO_4$ redox=7