

**THE STUDY OF IONS AND SALTS
IN CHEMISTRY**

CHAPTER 1: INTRODUCTION TO IONS AND IONIC COMPOUNDS

1.1. Introduction

Until far, we have discussed solely the neutrally charged elemental types of atoms. It is because the total number of electrons (charged negatively) equals the total no. of protons (positively charged particle). Since an amount of negative charge is equivalent as the amount of the positive charge, the total charge on the atom is nil. However, this one-to-one charge ratio is not the most frequent condition for a large number of elements. Disorders therefore in ratio result in the formation of charged particles termed ions (Koppenol, 2002; Poulsen, 2010; Ball et al., 2011).

Across nature, high-energy objects flow to lesser-energy positions. Because lesser energy structures are extra stable things move toward these things. These lesser energy variables express as noble gas components in terms of atoms. These elements have entire valence electronic configurations. it renders them as sustainable and inert. Because they are as in a lesser energy state, they have ability to remain in that condition (Bewick, 1969; Hirschhorn et al., 2001; Bernhoft, 2012).

1.1.1. Octet Rule

The elements from the other classes have configurations, of partial valence electron making them unstable as matched to noble gases. That instability pushes these elements near to lower energy levels shown by nearby noble gases in periodic table. The outermost energy states in these lower energy levels includes eight electrons (an "octet"). The "Octet Rule" refers to an atom's proclivity for a configuration where it has eight valence electrons (Gillespie & Silvi, 2002; Saito et al., 2009).

An atom lacking an octet of electrons in outermost shell can gain an octet in valence shell in one of two ways. One method is to transfer electrons among two atoms till both have octets. There is no net change in the amount of electrons since a few atoms will drop electrons and other atoms will accept electrons, nonetheless along the transportation of energy, the distinct atoms gain other than zero charge (Lever, 1972; Schleyer et al., 1982). The one who take in electrons convert to positively charged, while the one who lose them convert to negatively charged. It's important to remember that ions are atoms that have a positive or negative charge. An anion is a negative charges atom with one or more electrons added to it (Linnett, 1961; Noury et al., 2002). However, when an atom drops either one or more than one electrons, this develop a cation, which is a positively charged atom. These positive and negative charges approach one other as opposing charges attract (and comparable charges repel), resulting in the creation of ionic bonds. The resultant chemicals are ionic compounds (Gillespie & Robinson, 2007; Quayle et al., 2015).

Another way the atom might acquire the octet of electrons by sharing electrons with other atom. Those paired electrons fill the outermost shells of these two atoms at a same moment. A covalent bond is formed when electrons are shared (Joki & Aksela, 2018).

1.1.2. Electron Dot Symbols in Periodic Table

This is easy as to determine amount of outer shell electrons at every element of the periodic table. Periodic table separates into two groups: transition elements and main group elements. Elements of principal group are designated by the letters IA through VIIIA, as well as the number of valence shell electrons corresponds as the group number (Figure 1.1). For instance, in halogen family, all elements are in VIIA group and contain seven electrons at its outermost shell. The valence shells of all transition inner elements and transition element contain totally two electrons (Railsback, 2003; Jena, 2013).

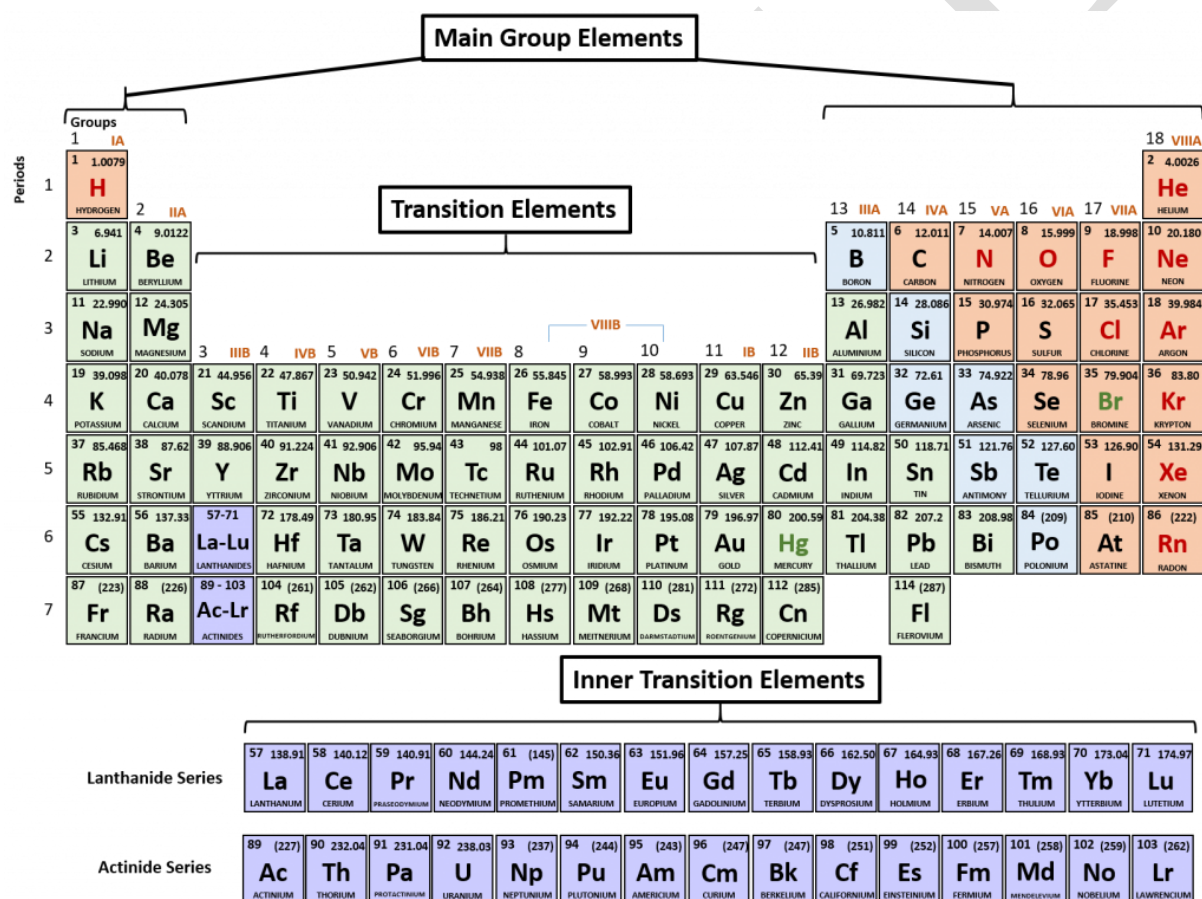


Figure 1.1. Elements Periodic Table. The components of the main group, transition, and inner transition are shown.

Though that is quite simple as for specify quantity of outer shells electron with numbers, a graphical presentation is generally useful. An Electron-Dot Symbol is the graphic representation for valence electrons. Begin by drawing an electron dot symbol along with acronym for interested element at center, representing nucleus of atom. Then, based on atom's location on the periodic table, find no. of outer

electrons it contains, as well as put a single dot for every outermost electron all about element (Fontani et al., 2015; Kwatra, 2017). Students frequently need to arbitrarily position those electron dots about element, but then again it is helpful to utilize the 4 cardinal directions like a guidance. Occupy single electrons in every of 4 cardinal places surrounding the atom till you are out of electrons. When it comes to elements with higher than four outermost electrons, we'll start combining these electrons in 4 cardinal directions (Lengler & Eppler, 2007; Farooq et al., 2020). It should be noted that noble gases contain full octets as well as would have eight electrons in the outermost shell (Figure 1.2).



Figure 1.2. Dot Symbols of Electrons

Note:

On the Periodic Table, electron dot symbols be displayed for Carbon with Neon. Before electrons are coupled with another electron, one electron would positioned at every one of 4 cardinal directions.

Overall, the periodic table may be utilized to find the no. of outer electrons in every element (Figure 1.3).

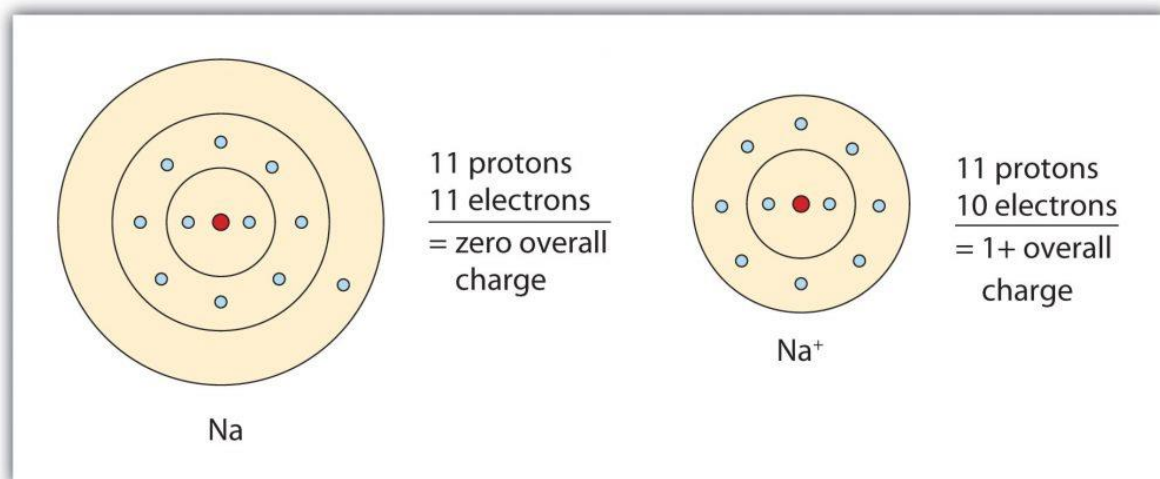


Figure 1.4. Sodium Ion formation

Source: <https://www.gcscience.com/a4-sodium-ion.htm>

Note:

It should be noted that sodium is capable of dropping its outermost shell electrons in the third shell at the time of the creation of an ionic connection. It now contains the electronic configuration of neon and does not have a complete octet in the second shell. This is important to notice that this ion still contains the similar number of protons (11) like an actual sodium atom and keeps its sodium character. Though, the electron cloud now has only 10 electrons, resulting in an overall positive (+1) charge (Nadeau et al., 1997; Pyykkö, 2011).

The sodium ion possesses an octet of electrons at the second major energy state as a result of losing that electron. The sodium ion's electron configuration is identical to a noble gas, neon. The ion and atom of separate atoms (or two distinct ions) with a similar electronic configuration are referred to as isoelectronic. The sodium ion and a neon atom are isoelectronic.

To attain the electronic configuration of a noble gas succeeding ions/atoms at the periodic table, IA Group elements will drop one electron overall. It is worth noting that the atom's nucleus stays constant, and so the identification of the ion remains unchanged. The electronic configuration of a sodium ion is similar to that of neon, but not a proton/neutron configuration. As a result, even after losing an electron, it keeps its identification as the element sodium. Likewise, Group IIA elements drop two outer electrons to produce +2 ions, moreover Group IIIA elements drop 3 electrons to generate +3 ions. In the periodic table, this provides them along the configuration of electrons of noble gas beside them (Vinogradov et al., 2003; Chen et al., 2018).

Although the first column contains hydrogen atom, this is not classified as an alkali metal, hence this is not classified in the way similar to the way of elements beneath this in the periodic table. This is due to the fact that hydrogen is extremely tiny and can only hold a total of two electrons before becoming full. It

deviates from the Octet Rule. As a result, rather of obeying the octet rule, this achieves more constancy by accumulating electrons of "duet" by associating with some other atoms. Based on the element with which it interacts, hydrogen could create both ionic and covalent bonds. When it forms ionic connections, it usually loses an electron, generating cation of a +1. Since hydrogen contains a single electron to start with, while it drops one electron in ionic form, there is just one proton remaining in a atom's nucleus. As a result, when hydrogen is ionized to H^+ , this is commonly known as a proton. This may also be ionized, resulting in the formation of a -1 anion. In this scenario, the hydride ion is formed by naming the H^- anion according to conventional procedure. The H^+ state is much more prevalent during hydrogen ionization than the H^- form. Furthermore, the ion of H^+ is crucial in the acidic chemistry. In aqueous solutions, acids describe like substances that give H^+ ions.

Cations are known just by adding a word 'ion' after an element name. As a result, an atom of sodium which has dropped electrons is already known as sodium ion

1.2.2. Common Anions

Non-metals, on the other hand, prefer to accept electrons so as to achieve a steady electronic configuration of noble gases which precede the noble gases in the periodic table.

Ionized Group VIIA elements acquire an electron and have negative charge. When chloride (Cl) is charged, it gains one electron, enabling it to achieve the electrical configuration of such a noble gas that leads to argon in the periodic table, as shown in Figure 4.5. This provides this a single negative charge then turns it into the chloride ion (Cl^-); notice the little variation in suffix (-ide rather than -ine) that results in an anion's name.

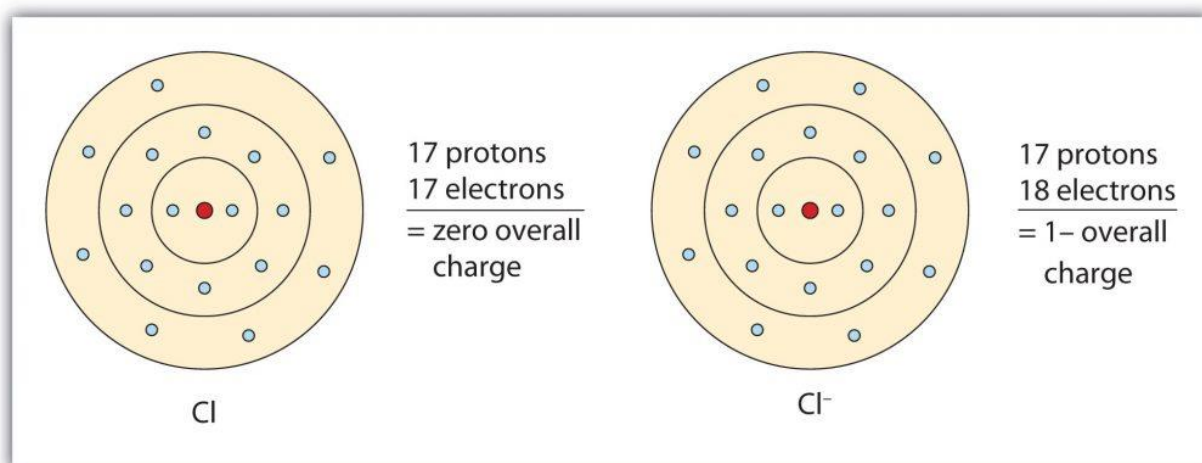


Figure 1.5. The Creation of Chloride Ion

Source: https://chem.libretexts.org/Courses/can/health/03%3A_Ionic_Bonding_and_Simple_Ionic_Compounds/3.3%3A_Ions

Note:

On the left, the chlorine atom possesses 17 electrons. A chloride ion has gained one electron to the right, providing it a maximum eighteen electrons and 1- charge. The chloride ion's outer layer is now completely filled and thus have eight electrons, according to the octet rule.

When elements of Group VIA are ionized, they acquire two electrons, resulting in charges of -2 and corresponding to the electronic configurations of noble gases which lead them in periodic table. On the other hand, elements of Group VA receive three electrons, giving in -3 charges and resembling the electrical configurations of noble gases seen earlier in periodic table.

This is critical just not to mistake an idea of isoelectronicity. Since the nuclei of a sodium ion and a neon atom have different amounts of protons, they are quite different. One is an important ion found in table salt, whereas other is an inert gas found in very minute amounts in the environment. Similarly, sodium ions differ significantly from fluoride ions, magnesium ions, and other all the components of neon isoelectronic series (Mg^{2+} , N_3 , Ne , O_2 , Al^{3+} , Na^+ , F).



Figure 1.6. Isoelectric Atoms contain Distinct features

Source: <https://www.ck12.org/chemistry/anion-formation/lesson/Anion-Formation-CHEM/>

Note:

Keep an eye out for the neon gas (A) and the sodium chloride crystals (B). Neon atoms and the ions of Sodium are isoelectronic elements. Neon is like a colourless, nonreactive gas that emits an unusual red-orange tint when discharged via the gas discharge tube. Sodium ions are often present in salt crystals, like as sodium chloride, which would be commonly used as table salt.

1.2.3. Ions of Transition and Inner Transition Metals

The transitional and inner metals, they are just the important as well as complex category of elements to study. These elements have confusing electron distribution designs that do not always obey the

electron filling principles. It is also not always easy to predict how they should form ions. To identify the ionic forms of inner and transition elements, see the general ion periodic table (Figure 1.7).

Common Ionic States of the Elements

+1										+2										+3										-3										-2										-1										Atomic number									
1 H H ⁺ HYDROGEN																				2 He HELIUM																																																	
3 Li LITHIUM	4 Be BERYLLIUM																				5 B BORON	6 C CARBON	7 N NITROGEN	8 O OXYGEN	9 F FLUORINE	10 Ne NEON																																											
11 Na SODIUM	12 Mg MAGNESIUM																				13 Al ALUMINIUM	14 Si SILICON	15 P PHOSPHORUS	16 S SULFUR	17 Cl CHLORINE	18 Ar ARGON																																											
19 K POTASSIUM	20 Ca CALCIUM	21 Sc SCANDIUM	22 Ti TITANIUM	23 V VANADIUM	24 Cr CHROMIUM	25 Mn MANGANESE	26 Fe IRON	27 Co COBALT	28 Ni NICKEL	29 Cu COPPER	30 Zn ZINC	31 Ga GALLIUM	32 Ge GERMANIUM	33 As ARSENIC	34 Se SELENIUM	35 Br BROMINE	36 Kr KRYPTON																																																				
37 Rb RUBIDIUM	38 Sr STRONTIUM	39 Y YTTORIUM	40 Zr ZIRCONIUM	41 Nb NIOBIUM	42 Mo MOLYBDENUM	43 Tc TECHNETIUM	44 Ru RUTHENIUM	45 Rh RHODIUM	46 Pd PALLADIUM	47 Ag SILVER	48 Cd CADMIUM	49 In INDIUM	50 Sn TIN	51 Sb ANTIMONY	52 Te TELLURIUM	53 I IODINE	54 Xe XENON																																																				
55 Cs CESIUM	56 Ba BARIUM	71 Lu LUTETIUM	72 Hf HAFNIUM	73 Ta TANTALUM	74 W TUNGSTEN	75 Re RHENIUM	76 Os OSMIUM	77 Ir IRIDIUM	78 Pt PLATINUM	79 Au GOLD	80 Hg MERCURY	81 Tl THALLIUM	82 Pb LEAD	83 Bi BISMUTH	84 Po POLONIUM	85 At ASTATINE	86 Rn RADON																																																				
87 Fr FRANCIUM	88 Ra RADIUM	103 Lr LAWRENCIUM	57 La LANTHANUM	58 Ce CERIUM	59 Pr PRASEODYMIUM	60 Nd NEODYMIUM	61 Pm PROMETHIUM	62 Sm SAMARIUM	63 Eu EUROPIUM	64 Gd GADOLINIUM	65 Tb TERBIUM	66 Dy DYSPROSIUM	67 Ho HOLMIUM	68 Er ERBIUM	69 Tm THULIUM	70 Yb YTTERIUM																																																					
			89 Ac ACTINIUM	90 Th THORIUM	91 Pa PROTACTINIUM	92 U URANIUM	93 Np NEPTUNIUM	94 Pu PLUTONIUM	95 Am AMERICIUM	96 Cm CURIUM	97 Bk BERKELIUM	98 Cf CALIFORNIUM	99 Es EINSTEINIUM	100 Fm FERMIUM	101 Md MENDELEVIUM	102 No NOBELIUM																																																					

Common ionic state → 1
H⁺
HYDROGEN ← Element name

Figure 1.7. General elemental ionic states.

Source: <https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-3-ions-and-ionic-compounds/>

Note:

Both ionic states are provided for the elements which contain more than a general ionic state. When mercury has a positive charge, this produces an unusual polyatomic ionic phase called Hg_2^{2+} , in which two mercury atoms swap electrons and every has a positive charge.

1.3. Ionic Bonding

The majority of minerals and rocks that comprise the crust of earth are made up of positively charged and negatively charged ions that bound with each other through ionic bonding. The ionic compound is a chemical substance that is electrically neutral and contains both ionic compounds. A few ionic chemicals, like sodium chloride, are well known to you (NaCl). A sodium chloride particle is made up of equal parts positive charged sodium ions (Na^+) as well as negative charged chloride ion (Cl^-).

The charges of anions and cations are fundamentally opposed. As a result, they are drawn to one another. An ionic bond can be formed whenever a cation and an anion are pulled together by electrostatic attraction. This sort of connection is formed by opposite charges attracted one another and differs from the other forms of bonding. An ionic compound is made up of two or more ions that are held together by electrostatic attraction. Binary ionic compounds, or these with two atoms, one serving

like an anion and other as cation, are the simplest ionic compounds. As a result, we shall first concentrate on creation of the binary ionic compounds (Taber, 1997; Coll et al., 2003).

Ionic substances include table salt and sodium chloride. Let's do a deeper observation at in what way it happened. In the development of sodium chloride, an electron released by sodium is picked up by chlorine, resulting in a formation of the chloride ion. This chloride ion contain one additional electron, providing it a negatively charge. The sodium cationic component and chloride anionic component is becoming electrostatically bound as a consequence of the electron transfer, forming sodium chloride, an ionic bond. It is critical to understand that electrons could not be "lost" somewhere; they constantly finish up going to the other molecule or atom. Ionic processes may be shown using electron dot diagrams, as illustrated below for NaCl (Schäfer et al., 1973; Di Girolamo et al., 1977):

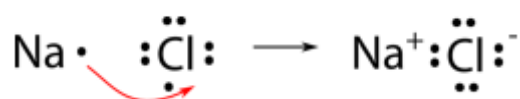


Figure 1.8. Ionic bonding of sodium chloride

Source:

[https://chem.libretexts.org/Bookshelves/Environmental_Chemistry/Green_Chemistry_and_the_Ten_Commandments_of_Sustainability_\(Manahan\)/04%3A_Compounds-_Safer_Materials_for_a_Safer_World/4.03%3A_Sodium_Chloride_and_Ionic_Bonds](https://chem.libretexts.org/Bookshelves/Environmental_Chemistry/Green_Chemistry_and_the_Ten_Commandments_of_Sustainability_(Manahan)/04%3A_Compounds-_Safer_Materials_for_a_Safer_World/4.03%3A_Sodium_Chloride_and_Ionic_Bonds)

The ionic link is what causes the Na^+ ion's affinity for the Cl^- ion. To emphasize that the original energy level holding outermost electron has been depleted, the cationic particle is often shown without dots from around the symbol. The anion now has a complete octet of electrons. A chemical formula of sodium chloride is NaCl. It's worth noticing that the both ions are displayed, despite the fact that their charges aren't (Skomski et al., 2012; Vladušić et al., 2016). This is because the total charge on the molecule within ionic compounds remains zero, which means that the charge levels of a anion(s) and cation(s) included in the bond must always in paired in a way that the no. of positive charges equates the number of negative charges. For sodium chloride, it is a straightforward operation since one chlorine ion contain -1 charged and one sodium ion contain a positive charge +1, equating each other out to nil. It is likewise worth remembering that in chemical formulas, a cation is constantly stated initial, followed by the anion (Reed & Schleyer, 1990; Kang et al., 2017).

It is not as easy for a chemical like magnesium chloride. Due to the fact that magnesium possesses two outermost electrons, it must drop both to obtain the noble-gas structure. As a result, two chlorine atoms would be required.

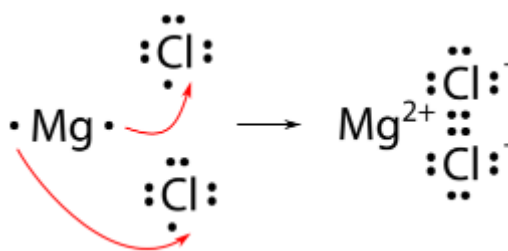


Figure 1.9. Magnesium chloride ionic connection

MgCl_2 is the chemical formula for magnesium chloride. The subscript (2) adjacent to chloride ion shows that each magnesium cation is linked with two chloride ions. While there is just single ion found in a formula (in this case, magnesium), the subscript of each is suggested rather than shown in the formula. There have been no charge seen in final chemical formula of MgCl_2 , as there are in the case of NaCl . Its because of the cation of magnesium ion (+2) is neutralized by negatively charged of two chloride ions [$2 \times (-1) = -2$], resulting in net charge of zero for the whole molecule (Taber et al., 2012; Luxford & Bretz, 2014).

1.4. Practice Writing Correct Ionic Formulas

To approximate and record suitable chemical formulas, first understand the ionic charge state, then use basic math to determine how many anions and cations are required to achieve a nil charge, then (3) write the chemical formulas with the cation first, then the anion, and finally (4) write the formula with the smallest ratio of anions and cations to produce an overall neutral compound (Pauling, 1933; Dehmer & Fano, 1970).

Ionic bonding happens when an anion (electron acceptor) likewise a cation (electron donor) come together to produce a molecule with a neutral net charge. Ionic bonds are most commonly formed between metals and nonmetals. Once we know of covalent bond formation (which happens most typically amongst two nonmetals or nonmetal and a semimetal), this will make it easier to detect ionic compounds (metalloid).

Assume we need to create the chemically right formula for molecule with Fe_3^+ as a cation and Cl^- as an anion. We are not sure what the exact ionic formula is. To keep track of the number of ions used, their charges, and the overall negatively and positively charged number on the molecule, I propose drawing a charge box or a charge table. when starting this sort of issue. It's also a good idea to draw out all the electron dot symbols. An illustration of a basic charge box is as follows (Ruddick & Parrill, 2012):

	CATION	ANION	
CHARGE of ION			
# ATOMS			Total Charge (on the Molecule)
TOTAL ION CHARGE			

Let's put it to the test using Fe_3^+ and Cl^- . Let's start by filling the blanks for every element as well as its ionic state (Jia, 1991; Morris, (2011):

	Fe	Cl	
CHARGE of ION	+3	-1	
# ATOMS			Total Charge (on the Molecule)
TOTAL ION CHARGE			

Thus now we've got the charge box set by all of our identified data. We must determine how so many cation and anion atoms are necessary to balance out the total positively and negatively charged on the final molecule. To achieve this, try to use the no. of the cations as the no. of anion necessary, and the no. of the anion as that of the no. of cation needed. Compute the overall ion charge of the anion(s) and cation(s) found by multiplying each ion charge by the number of atoms, and then adding these numbers collectively determine the overall charge on complex. It will almost always lead to a stable ionic formula with overall neutral charge of zero (Bent, 1953; Zhou et al., 2011).



	Fe	Cl	
CHARGE of ION	+3	-1	
# ATOMS	1	3	Total Charge (on the Molecule)
TOTAL ION CHARGE	+3	-3	= 0

The subscripts from the no. of atoms column are then used to generate the right ionic formula. In this scenario, FeCl₃ is formed by combining three atoms of chlorine (Cl) with one atom of iron (Fe).

The last example is rather simple, and you might be able to figure out the formula in your head. Though, as the intricacy of formula creation grows, being capable using the charge box approach to dual-check your work becomes more important. What is the right ionic formula for aluminium sulphide, for instance? To begin, define two atoms required (Aluminum and Sulfur) using what you understand from the periodic table to design your charge box. Aluminum creates a cation with a +3 charge, while sulphur generates the anion with such a -2 charge phase (Glasser & Jenkins, 2000).

	Al	S	
CHARGE of ION	+3	-2	
# ATOMS	2	3	Total Charge (on the Molecule)
TOTAL ION CHARGE	+6	-6	= 0

Step 1: Calculate the right charge for the anions and cations in issue, which is -2 for S and +3 for Al in this example. Step 2: Both for anions and cations, just use cross multiply rule for forecasting in what way so many atoms will be required out of every type and multiplied by the total ion charge. Step 3: Combine the products to ensure whether your compound is sustainable and that the formula's net charge is zero. Step 4: Generate the subscripts to your molecular formula using the # Atoms value. In our case, we'll need 2 Al atoms and 3 S atoms. As the end result, it would be represented as Al₂S₃ (Xu & Ching, 1991; Gillot et al., 1992).

1.5. Naming Ions and Ionic Compounds

Water (H₂O) is a popular name for certain substances. Thousands of other compounds, on the other hand, are rare or have several names. Furthermore, the general name is hardly recognized outside of the United States. What you see as water may appear to someone else as *agua* or *vatten*. There are naming rules for determining a systematic name of chemical so that chemists may interact without being confused. We shall mostly use the International Union of Pure and Applied Chemistry (IUPAC) name system for the chemistry naming system in this article. In addition to the IUPAC system, there is an earlier and much more system for archaic (-ous and -ic) naming. In certain cases, the earlier name scheme is still widely used. These departures from of the IUPAC system would be acknowledged throughout the book, as this older terminology is still widely used in chemical labs and the health sciences (Wirtz et al., 2006; Kavak, 2012).

The name of cations adheres to a straightforward convention. It's as easy as adding 'ion' to an end of an element name. The term sodium ion refers to a sodium atom that has dropped an electron (Na⁺). This indicates that the sodium would have a +1 positive electrical charge, as compared to its elemental state (which has similar no. of electrons and protons and is neutral in charge). When referring to ions, it is critical to utilize the ion naming system other than the element names of atoms, since sensitivity of an ion vs. the elemental form of material might be pretty different. For instance, if you add the sodium ion in the form of NaCl (or table salt) to a glass of drinking water, you'll get a salty, pleasant drink. However, if you put elemental sodium in your glass full of water, it will burst in your face since elemental sodium is very reactive with water!

To distinguish the many ionic forms in cations with more than one charge phase, a term atom is led by a roman number value as well as afterwards the word ion. For instance, iron exists in two primary ionic forms: Fe²⁺ and Fe³⁺. As a consequence, the first ion is known as an iron (II) ion, while the second is known as an iron (III) ion. it removes any question about whether an ion is being addressed while calling a compound (Baker & Ollis, 1957; Lind, 1992).

Anions are a bit trickier to identify. The element's end is frequently removed in favor of the word ion followed by the word *ide*. Cl⁻, for example, refers to it as the chloride rather than the chlorine ion. In this scenario, the '-ine' end of chlorine is substituted with the 'ide' end. To create the sulfide ion, the '-ur' ending is removed and substituted with 'ide.' Phosphorus is transformed to the phosphide ion, nitrogen to the nitride ion, and oxygen to the oxide ion in the same manner (Goodenough et al., 1961; Churchman & Carr, 1975). The '-ide' ending is significant as it benefits the hearer to rapidly differentiate among the two kinds of ions being named (the cation, that recollects the element label, and an anion, that adds the '-ide' ending).

A word ion is deleted when identifying ionic compounds, and the names of the anions and cations are combined, with cation always stated first then the anion mentioned last. There is no need for roman

numerals in the name if the components include in the ionic connection only contain one potential ionic state. Whenever the Na^+ and Cl^- atoms combine to form NaCl , the resultant chemical is known as sodium chloride. When Mg^{2+} and Cl^- combine to form MgCl_2 , the resultant chemical is known as magnesium chloride. When the components in an ionic bond contain much more than one conceivable ionic state, the roman numerical value scheme is employed to determine that ion is involved in the bond. For instance, if Fe_3^+ and Cl^- react to generate FeCl_3 , we'll have to differentiate it from Fe_2^+ and Cl^- reacting to generate FeCl_2 in a term so now everyone knows whichever ion of iron has been discussed in the reaction. The first component will be iron (III) chloride, while the second compound will be iron (II) chloride in this case (Wulfsberg et al., 2006; Thong et al., 2015).

While it arises to naming ionic compounds, the most significant thing to recall is that you'll be capable of drawing the shape from the name and build the term from the structure. Let's put our skills to the test!

1.6. Polyatomic Ions

Till recently, we have focused on compounds containing monoatomic ions, or ions formed by a single atom. Though, a few regularly occurring ions are made of several atoms which are joined together by electron sharing or covalent bonds. These ions operate identically to monatomic ions, possessing a charge and reacting with some other ions and molecules. Due to the fact that these ions are composed of many atoms, they are referred to as polyatomic ions. Negatively charged polyatomic ions are more prevalent than positively charged polyatomic ions. The chart below illustrates some of the more often found polyatomic ions (Cooks et al., 1990; Shvartsburg & Jarrold, 1996).

Table 1.1. Frequently Used Polyatomic Ions

Common Polyatomic Ions			
$\text{C}_2\text{H}_3\text{O}_2^-$	acetate	OH^-	hydroxide
NH_4^+	ammonium	ClO^-	hypochlorite
CO_3^{2-}	carbonate	NO_3^-	nitrate
ClO_3^-	chlorate	NO_2^-	nitrite
ClO_2^-	chlorite	$\text{C}_2\text{O}_4^{2-}$	oxalate
CrO_4^{2-}	chromate	ClO_4^-	perchlorate
CN^-	cyanide	MnO_4^-	permanganate
$\text{Cr}_2\text{O}_7^{2-}$	dichromate	PO_4^{3-}	phosphate
HCO_3^-	bicarbonate	SO_4^{2-}	sulfate
HSO_4^-	bisulfate	SO_3^{2-}	sulfite
HSO_3^-	bisulfite		

Source: <https://cpanhd.sitehost.iu.edu/C101webnotes/chemical-nomenclature/polyatomsalts.html>

Polyatomic ions are identical to monoatomic ions in that they are ionised by acquiring or releasing electrons to acquire a charge. They will form an anion if they receive electrons, and a cation if they release electron. A polyatomic ion's charge is indicated by a superscript located at the ion's top righthand edge. For instance, the chemical formula for the phosphate ion is PO_4^{3-} . This means the whole PO_4 molecule has a -3 charge, and thus when it is used to produce an ionic compound, the whole PO_4^{3-} ion moves and is considered as a single unit. Let us begin by attempting to synthesise a few molecules utilizing phosphate as an illustration. To begin, let us construct a sodium phosphate molecule. Take note that when asked to create compounds based on their names, you can frequently tell when you do have a polyatomic ion. Remember that monoatomic anions are suffixed with '-ide'. Therefore, when you come across a distinct suffix ending, including such '-ate' or '-ite', you should be aware that you are dealing with a polyatomic ion and should check the table above should identify the exact ion formula to use. For sodium phosphate, you can create this molecule using the same charge box diagram which you used to produce the smaller biatomic structures above. To begin, we must organize the ions in the table according to their charged states. In this case, sodium is a positively charged cation, while phosphate is a negatively charged anion (Bates, 1986; Miller et al., 1997).

	Na	PO₄	
CHARGE of ION	+1	-3	
# ATOMS			Total Charge (on the Molecule)
TOTAL ION CHARGE			

Take a look that we are considering the polyatomic ion like on entity in our table. We can next apply our cross multiplication technique to find the no. of anions and cations required to generate an overall neutral molecule.

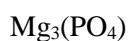
	Na	PO ₄	
CHARGE of ION	+1	-3	
# ATOMS	3	1	Total Charge (on the Molecule)
TOTAL ION CHARGE	+3	-3	= 0

Thus, we will require three sodium atoms and one phosphate molecule to finish our structure. In general, sodium phosphate is denoted by the chemical formula Na₃PO₄. Take note that the resultant molecule is named identically to that of other ionic compounds. The cation's name is given first (in roman numeric where necessary), followed by the anion's name (in this phosphate case).

Maybe a more complex illustration? How might we synthesize a magnesium phosphate molecule? Begin by constructing your molecule by means of charged box diagram, noticing that magnesium creates a Mg²⁺ ion at this point (Houk & Praphairaksit, 2001; Sakata & Kawabata, 1994).

	Mg	PO ₄	
CHARGE of ION	+2	-3	
# ATOMS	3	2	Total Charge (on the Molecule)
TOTAL ION CHARGE	+6	-6	= 0

Setting the charge box for such a compound is comparable to establishing the charge box for any other compound. However, caution should be exercised when drawing up chemical formulas that contain more than one polyatomic ion. Two phosphate ions must mix with three magnesium ions to generate magnesium phosphate in this scenario. A cation is written identically in this example, though parentheses are required when stating the two phosphate ions as follows (Patil et al., 2020):



The parenthesis surrounding the phosphate ion indicate which this combination requires two complete PO₄³⁻ ions. The structural diagram of that molecule is presented underneath. Keep in mind that each

straight line represents a covalent link inside the phosphate ion. Each straight line indicates the sharing of pair of electrons (or 02 electrons) among two atoms. Chapter 4 will discuss covalent bonding in greater depth. For the time being, it is significant to realize as the polyatomic ions flow in unison since the atoms sharing electrons essentially maintain closeness to one another. The (-) and (+) symbols denote the ionic bonding. Magnesium phosphate forms a total of six ionic bonds (Lifshitz, 1983).

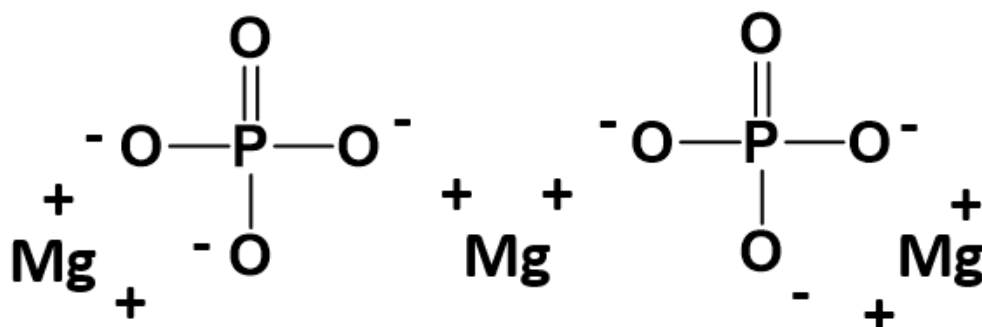


Figure 1.10. Ionic bonding in magnesium phosphate

Source: https://www.softschools.com/formulas/chemistry/magnesium_phosphate_formula/573/

Another peculiar substance is mercury (I) chloride. This is the exemption to the standard bonding procedures. We would assume that mercury (I) chloride has the chemical formula $HgCl$ based on charge possibilities, even as chloride ion does have a charge of -1 while mercury (I) is supposed to hold a charge of +1. This formula, though, formula is wrong in this specific case. Mercury is unique in that its single ionized oxidation configuration, mercury(I), is seen as a dimeric cation, Hg_2^{2+} , in which two mercury atoms are covalently bound to form a polyatomic ion. Every mercury atom in the bound pair is in the positive charge state. This results in a +2 state for the total ion, as seen below (Wytttenbach et al., 2013):

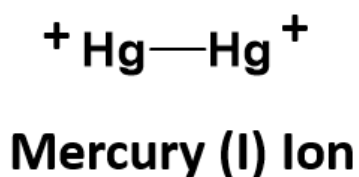
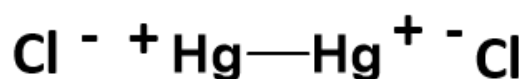


Figure 1.11. Mercury ions in the Hg-Hg bond

Source: <https://wou.edu/chemistry/courses/online-chemistry-textbooks/3890-2/ch104-chapter-3-ions-and-ionic-compounds/>

Regrettably, this polyatomic ion lacks a distinctive name which differentiates it from conventional monoatomic cations. As a result, you'll have to recognize this one-of-a-kind individual. For a minimum

chemical formula of Hg_2Cl_2 , the complete chemical formula of mercury (I) chloride requires two chloride ions to finish the structure.



Mercury (I) Chloride

Figure 1.12. Bonding of Mercury chloride

Source: https://www.softschools.com/formulas/chemistry/mercury_ii_chloride_formula/463/

Although mercury (I) chloride is uncommon naturally, it was widely utilized in the 1800s and 1900s as a medication for treating infectious disorders such as yellow fever and syphilis. Additionally, it was taken as a common tonic to induce regurgitation and cleanse the body of 'impurities'. Calomel caused serious negative impacts and cytotoxicity during its medicinal usage, resulting in hair and tooth loss. Indeed, calomel was a popular component in teething powders in the United Kingdom until 1954, resulting in large amount of mercury poisoning with in type of pink illness, which had a fatality rate of one in ten at the time. Mercury was eliminated from these powders once the aetiology of pink sickness was attributed to mercury poisoning. In the United States, the use of it declined in the late 1800s as more effective therapies became available, such as Alexander Flemming's late-nineteenth-century discovery of penicillin (Patterson, 1972).

1.6.1. Abraham Lincoln and “Blue Mass”

In the Civil War era, "blue mass," a drug composed of elemental mercury and different additions, was widely utilized to treat a variety of conditions. While mercury was the recognized toxicity, this was a common component of medical treatment for "hypochondriasis," an illness which encompassed a variety of what we now refer to as mood disorders, as well as digestive system difficulties. Abraham Lincoln was found to suffer from hypochondriasis and was prescribed blue mass medicine. Interestingly, colleagues and acquaintances reported that he suffered from sleeplessness and mood swings, and there is some indication that he had further neurological problems. These are mercury poisoning symptoms. Within the body, uncharged elemental mercury is converted to mercuric mercury (Hg^{2+}), that has a +2 charge. This type of mercury is extremely toxic to a variety of physiological systems, resulting in malfunction that may have contributed to Abraham Lincoln's symptoms. Because of medicine's absence of knowledge, his therapy may be more detrimental than the conditions in which it was designed.

1.6.2. Naming Polyatomic Ions

As seen in Table 4.1, polyatomic ions have distinct names. A few of them have oxygen and are known as oxyanions. When an element has just one oxyanion, the primary element's end is provided the '-ate' ending. Carbonate, for instance, is a carbon oxyanion (CO_3^{2-}). However, suffixes & prefixes are being used to differentiate separate oxyanions that utilize the similar element but have a varied amount of oxygen atoms. For example, if two oxyanions arise, anything with lesser oxygens is provided the '-ite' ending, whereas the one element with more oxygens is given the '-ate' ending. Nitrogen and sulphur oxyanions being excellent examples:

Nitrite is the name given to NO_2^- .

NO_3^- is known as Nitrate SO_3^{2-} is known as Sulfite SO_4^{2-} is known as Sulfate

There may well be 3 to 4 oxyanions at times. At this situation, the prefix 'hypo-' would be utilized to denote one little oxygen than the '-ite' version. While there are four oxyaions, also there has a 'per-' prefix, which means that there is one extra oxygen than in the '-ate' form. The chlorinated family of ions is indeed a good illustration of when these prefixes are required.

ClO^- is referred to as hypochlorite.

ClO_2^- is also known as chlorite.

ClO_3^- is referred to as chlorate.

Perchlorate is the chemical formula for ClO_4^-

You may come across a bi- prefix on occasion. This is an ancient prefix that signifies the chemical may both pick up and losing a proton (H^+). The IUPAC nomenclature would utilise hydrogen in the name, but the earlier nomenclature would use the bi-prefix. In both instance, the oxyanion will also have a hydrogen atom in it, reducing its charge by the one. Hydrogen carbonate (HCO_3^-) and Carbonate (CO_3^{2-}) are two examples. Hydrogen carbonate is also known as bicarbonate (Kollman et al., 1975).

Thio- is a final prefix you could come upon. It denotes that one oxygen has now been exchanged by a sulphur within the oxyanion. Cyanate is OCN^- , whereas thiocyanate is SCN^- .

Ionic compounds containing polyatomic ions are named in the similar manner that some extra binaries ionic compounds are. A label of the cation goes first (with roman numerals where required), preceded by the label of the anion. Specified in Table 4.1 to find the right nomenclature for such polyatomic ions (Yoder, 2006).

1.7. Properties and Types of Ionic Compounds

Electrostatic forces caused by the pull of positive charge cations and negative charges anions hold ionic compounds together. These can be simple ions, such as chloride (Cl) and sodium (Na⁺) or polyatomic species, such as carbonate (CO₃²⁻) and ammonium (NH₄⁺) ions in ammonium carbonate. Separate ions inside an ionic compound typically have many nearest, and hence are not regarded as a part of separate molecules, but rather as part of the continuous three-dimensional structure or lattice, which is frequently crystalline (Goodenough et al., 1961; Patil et al., 2016).

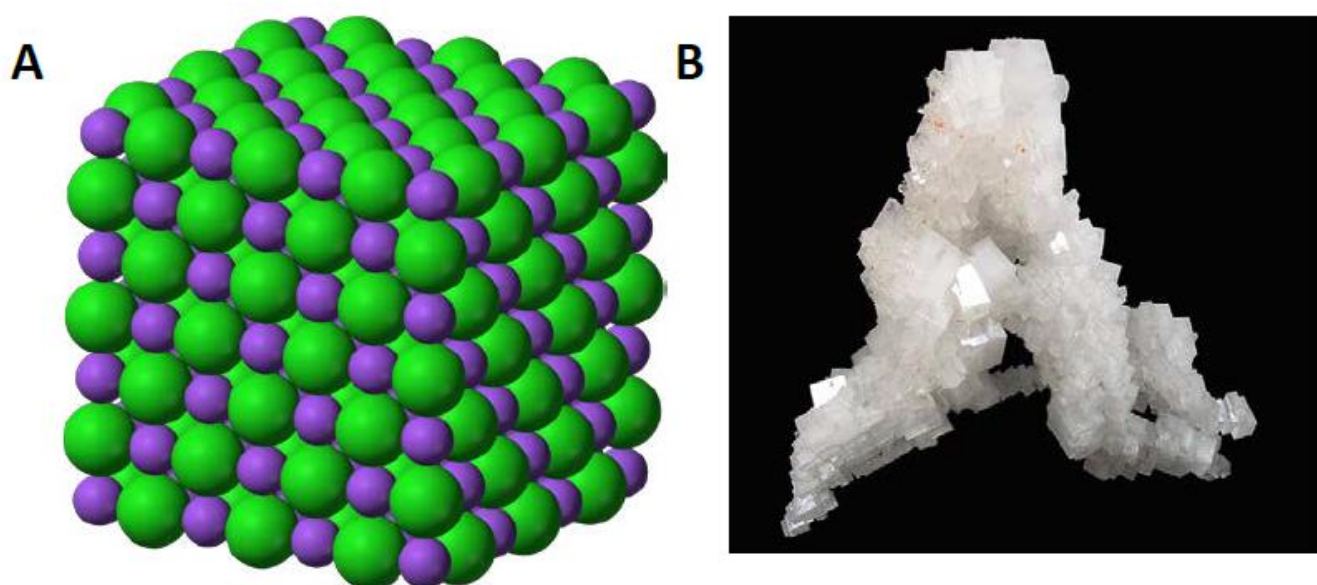


Figure 1.13. Lattice of Crystals (A) A common ionic compound, sodium chloride, NaCl, has a crystal structure. The purple spheres are sodium cations (Na⁺), whereas the green spheres are chloride anions (Cl). (B) When salty water evaporates, leaving the ions behind, halite, the crystalline form of sodium chloride, develops..

Source: https://en.wikipedia.org/wiki/Ionic_compound

Acids are ionic substances that contain hydrogen ions (H⁺), while bases include oxide (O₂) or hydroxide (OH) ions. Salts are any ionic compounds that do not contain these ions. Ionic substances are often hard and brittle, having high boiling and melting points. They are normally electrically insulated as solids, but when dissolved or melted, the ions become mobilized and exceedingly conductive. Electrolytes are ions that have been mobilized in a solution and have the ability to conduct electricity (Baker et al., 1949; 1950; Butts & Smith, 1987).