4.5.1: Ions - Monatomic and Polyatomic

Learning Objectives

Most atoms do not have eight electrons in their valence electron shell. Some atoms have only a few electrons in their outer shell, while some atoms lack only one or two electrons to have an octet. In cases where an atom has three or fewer valence electrons, the atom may lose those valence electrons quite easily until what remains is a lower shell that contains an octet. Atoms that lose electrons acquire a positive charge as a result because they are left with fewer negatively charged electrons to balance the positive charges of the protons in the nucleus. Positively charged ions are called **cations**. Most metals become cations when they make ionic compounds.

Cations

A neutral sodium atom is likely to achieve an octet in its outermost shell by losing its one valence electron.

$$\mathrm{Na} \rightarrow \mathrm{Na^+} + \mathrm{e^-} \tag{4.5.1.1}$$

The cation produced in this way, Na^+, is called the sodium ion to distinguish it from the element. The outermost shell of the sodium ion is the second electron shell, which has eight electrons in it. The octet rule has been satisfied. Figure $4.5.1.1$is a graphical depiction of this process.

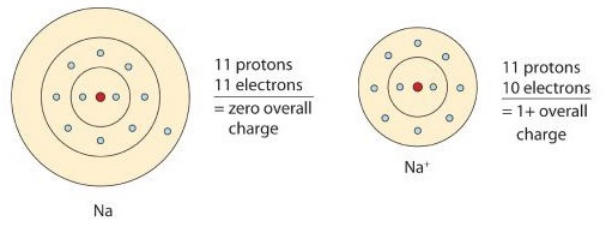

Figure $4.5.1.1$: The Formation of a Sodium Ion. On the left, a sodium atom has 11 electrons. On the right, the sodium ion only has 10 electrons and a 1+ charge.

Anions

Some atoms have nearly eight electrons in their valence shell and can gain additional valence electrons until they have an octet. When these atoms gain electrons, they acquire a negative charge because they now possess more electrons than protons. Negatively charged ions are called **anions**. Most nonmetals become anions when they make ionic compounds.

A neutral chlorine atom has seven electrons in its outermost shell. Only one more electron is needed to achieve an octet in chlorine's valence shell. (In table salt, this electron comes from the sodium atom.)

$$\mathrm{e^-} + \mathrm{Cl} \longrightarrow \mathrm{Cl^-} \tag{4.5.1.2}$$

In this case, the ion has the same outermost shell as the original atom, but now that shell has eight electrons in it. Once again, the octet rule has been satisfied. The resulting anion, Cl^-, is called the chloride ion; note the slight change in the suffix (*-ide* instead of *-ine*) to create the name of this anion. Figure $4.5.1.2$is a graphical depiction of this process.

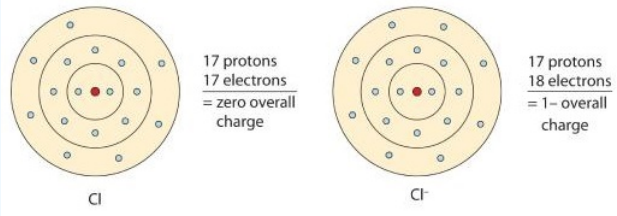

Figure $4.5.1.2$: The Formation of a Chlorine Ion. On the left, the chlorine atom has 17 electrons. On the right, the chloride ion has 18 electrons and has a 1− charge.

> *The names for positive and negative ions are pronounced CAT-eye-ons and ANN-eye-ons, respectively.*

In many cases, elements that belong to the same group (vertical column) on the periodic table form ions with the same charge because they have the same number of valence electrons. Thus, the periodic table becomes a tool for remembering the charges on many ions. For example, all ions made from alkali metals, the first column on the periodic table, have a 1+ charge. Ions made from alkaline earth metals, the second group on the periodic table, have a 2+ charge. On the other side of the periodic table, the next-to-last column, the halogens, form ions having a 1− charge. Figure 4.5.1.3 shows how the charge on many ions can be predicted by the location of an element on the periodic table. Note the convention of first writing the number and then the sign on a ion with multiple charges. The barium cation is written Ba^{2+}, not Ba^{+2}.

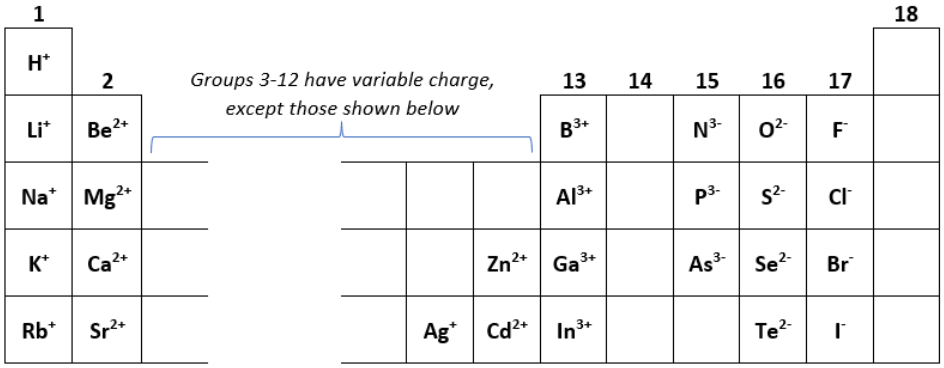

Figure 4.5.1.3: Predicting Ionic Charges. The charge that an atom acquires when it becomes an ion is related to the structure of the periodic table. Within a group (family) of elements, atoms form ions of a certain charge.

Polyatomic Ions

Some ions consist of groups of atoms bonded together and have an overall electric charge. Because these ions contain more than one atom, they are called polyatomic ions. Polyatomic ions have characteristic formulas, names, and charges that should be memorized. For example, NO_3^- is the nitrate ion; it has one nitrogen atom and three oxygen atoms and an overall 1− charge. Table 4.5.1.1 lists the most common polyatomic ions.

Selected Common Polyatomic Ions					
Formula	**Name**	**Formula**	**Name**	**Formula**	**Name**
H_3O^+	hydronium	NH_4^+	ammonium	Hg_2^{2+}	mercury(I)
OH^-	hydroxide	CN^-	cyanide	O_2^{2-}	peroxide
MnO_4^-	permanganate	CrO_4^{2-}	chromate	$Cr_2O_7^{2-}$	dichromate
$C_2O_4^{2-}$	oxalate	$C_2H_3O_2^-$ or CH_3COO^-		acetate	

Oxyanions Ending in "-ate"				
borate, BO_3^{3-}	carbonate, CO_3^{2-}	nitrate, NO_3^-		
	silicate, SiO_3^{2-}	phosphate, PO_4^{3-}	sulfate, SO_4^{2-}	chlorate, ClO_3^-
		arsenate, AsO_4^{3-}	selenate, SeO_4^{2-}	bromate, BrO_3^-
			tellurate, TeO_4^{2-}	iodate, IO_3^-

Naming Rules for Oxyanions (keep charges the same as -ate):		**Examples**
per-	one more oxygen (than -ate)	perchlorate, ClO_4^-
-ite	one less oxygen (than -ate)	chlorite, ClO_2^-
hypo-	one less oxygen (than -ite)	hypochlorite, ClO^-
thio-	replace one oxygen with one sulfur	thiosulfate, $S_2O_3^{2-}$

Naming Rules for Adding Hydrogens to Oxyanion (the charges change):		**Examples**
0 H^+	Normal anion name	phosphate, PO_4^{3-}
1 H^+	Add hydrogen as prefix (charge reduced by 1)	hydrogenphosphate, HPO_4^{2-}
2 H^+	Add dihydrogen as prefix (charge reduced by 1)	dihydrogenphosphate, $H_2PO_4^-$

Figure 4.5.1.3: Common Polyatomic Ion Charges

Here's a simple method for memorizing oxyanions ending in "-ate".

Contributions & Attributions

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