Chapter 4

The Ionic Bond

1. Define the term "isoelectronic".

Two atoms are isoelectronic when they have the same electron configuration.

3. Which of the following compounds are ionic?

a) KCN **b) HNO_2** **c) $CoPO_4$** **d) NH_4NO_2**

Ionic compounds contain either a metal or the ammonium ion, so a, c and d are ionic.

5. How can the number of electrons involved in metals and nonmetals achieving noble gas configurations be predicted for the main group (A Groups) elements?

The number of electrons gained by a nonmetal is eight minus its group number. The number lost by a metal is equal to its group number.

7. Oxygen can have a positive oxidation state when bound to only one element. What is the element? Use orbital energies to explain why this is so.

Fluorine in the only element with priority over oxygen that forms a negative ion. When O and F bond, F is –1, so O must be positive. The compound they form is OF_2, in which case the O is +2. The reason is that fluorine is the only element that is more electronegative, which means that its valence orbitals are lower in energy than those on O. Consequently, the bonding electrons are assigned to the fluorine when assigning oxidation states.

9. Which element in each pair that would have the positive oxidation state.

a) N & O **b) Cl & P** **c) S & Sn** **d) K & N**

The less electronegative element will have the positive oxidation state: N, P, Sn, and K

11. Write electron configurations for the following ions. Use the noble gas core abbreviations.

a) Ca^{2+} [Ar] **b) Ga^{3+}** [Ar] $3d^{10}$

c) Co^{3+} [Ar] $3d^6$ **d) I^{1-}** [Xe]

13. Explain the following observations.

a) K^{1+} is larger than Na^{1+}.

The size of the ions in a group increases going down the group because the n quantum number of the outermost electrons increases.

b) Na is larger than Cl, but Na^{1+} is much smaller than Cl^{1-}.

Na is larger than Cl because the effective nuclear charge experienced by the valence electrons is greater for Cl. Na^{1+} is isoelectronic with Ne and slightly smaller due to the additional proton while Cl^{1-} is isoelectronic with Ar, but it is slightly larger because Ar has one more proton, which increases its effective nuclear charge.

c) Lead forms two oxides, PbO and PbO_2.

Lead's valence electron configuration is $6s^2\ 6p^2$. It can lose the two 6p electrons to form a +2 ion as in PbO or it can lose all four to achieve the +4 oxidation state as in PbO_2

15. Determine the oxidation state of the underlined atom.

a) $\underline{C}_{60}$ C_{60} is an element and all atoms are therefore in the 0 oxidation state.

b) $Li\underline{Al}H_4$ Al has priority of H and is assigned a +3 oxidation state. Li is a +1, which means that H is -1. This compound is therefore a hydride, lithium aluminum hydride.

c) $\underline{O}F_2$ F is always -1 in its compounds with other elements so O is a +2 in this compound.

d) $Ca\underline{Si}O_3$ Ca is +2 and O is -2. +2 + y + 3(-2) = 0, so y = +4. This is calcium silicate.

17. Name the following compounds:

a) $Zn_3(PO_4)_2$ zinc phosphate. Because the d sublevel is full for Zn, it forms only the +2 ion.

b) Ag_2S silver sulfide. Silver is an exception to the rules for transition metals and only forms +1 ions.

c) Cr_2O_3 chromium(III) oxide. Chromium is a typical transition metal and adopts many oxidation states.

d) NH_4Cl ammonium chloride.

19. What two names can be used for $Ca(HCO_3)_2$? calcium hydrogen carbonate or calcium bicarbonate.

21. Predict the formulas of the vanadate and titanate ions.

Vanadium is a 5B and by analogy to the 5A's, the vanadate ion should have a formula similar to phosphate ion. The vanadate ion is VO_4^{3-}.

Titanium is a 4B metal and is expect to be in the +4 oxidation state in an -ate ion. By analogy to the 4A ions carbonate and silicate, the titanate ion is predicted to be TiO_3^{2-}.

23. Consider the compound formed between atoms Y and Z.

a) What are the maximum and minimum oxidation states of Y?

Since Y must lose six electrons to empty its valence orbitals, its maximum oxidation state is +6. It must gain two electrons to fill its valence shell so it minimum oxidation state is -2.

b) What are the maximum and minimum oxidation states of Z?

Z can lose five electrons and thus attain a +5 oxidation state. It requires three electrons to fill its valence orbitals to become a -3.

c) What is the formula of the compound Y and Z in their maximum and minimum oxidation states?

Z is the more electronegative atom and is assigned its minimum oxidation state of -3. Y is less electronegative and is assigned its +6 oxidation state. The formula is YZ_2.

25. Write formulas for the following compounds:

a) gallium(III) oxide Ga_2O_3

b) strontium bromide $SrBr_2$

c) zinc acetate $Zn(CH_3COO)_2$ or $Zn(C_2H_3O_2)_2$ acetate ion is represented by either formula. The first better indicates the structure of the ion, but both are common.

d) manganese(II) sulfide MnS

27. Write formulas for the following ionic compounds:

a) sodium bicarbonate: $NaHCO_3$ **b) iron(II) hydrogensulfate:** $Fe(HSO_4)_2$

c) calcium dihydrogenphosphate: $Ca(H_2PO_4)_2$ **d) magnesium hydrogensulfite:** $Mg(HSO_3)_2$

29. How many moles of iron(III) oxide are present in a 5.00-g sample?

$$5.00\text{ g } Fe_2O_3 \times \frac{1\text{ mol } Fe_2O_3}{159.7\text{ g } Fe_2O_3} = 0.0313\text{ mol } Fe_2O_3$$

31. A sample of calcium nitrate contains 0.025 mol of oxygen atoms. What is the mass of the sample?

$$0.025\text{ mol O} \times \frac{1\text{ mol } Ca(NO_3)_2}{6\text{ mol O}} \times \frac{164\text{ g } Ca(NO_3)_2}{\text{mol } Ca(NO_3)_2} = 0.68\text{ g } Ca(NO_3)_2$$

33. How many moles of protons are required to convert all of the phosphate ions in 25.0 g of magnesium phosphate into dihydrogen phosphate ions?

$$25.0\text{ g } Mg_3(PO_4)_2 \times \frac{1\text{ mol } Mg_3(PO_4)_2}{263\text{ g } Mg_3(PO_4)_2} \times \frac{2\text{ mol } PO_4^{3-}}{1\text{ mol } Mg_3(PO_4)_2} \times \frac{1\text{ mol } H_2PO_4^{1-}}{1\text{ mol } PO_4^{3-}} \times \frac{2\text{ mol } H^{1+}}{1\text{ mol } H_2PO_4^{1-}} = 0.380\text{ mol } H^{1+}$$

35. How many moles of electrons must be removed to convert 7.5 g Zn to zinc ions?

The Zn ion has a charge of +2, so 2 mol electrons must be removed for each mole of Zn

$$7.5\text{ g Zn} \times \frac{1\text{ mol Zn}}{65.4\text{ g Zn}} \times \frac{2\text{ mol electrons}}{1\text{ mol Zn}} = 0.23\text{ mol electrons}$$