Assessment and Evaluation

ThoughtLab/ ExpressLab/ Investigation	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Category	Learning Skills
ThoughtLab: Ionic or Covalent; page 68	■ [MCB V.01] demonstrate an understanding of the relationship between periodic tendencies, types of chemical bonding, and the properties of ionic and molecular compounds ■ [MCB V.03] describe how an understanding of matter and its properties can lead to the production of useful substances and new technologies	■ Student Answers to Questions ■ In-Class Discussion	■ Knowledge/ Understanding ■ Making Connections ■ Inquiry	■ Teamwork

Section 3.1

CHECKPOINT

Student Textbook page 71

The most electronegative element is fluorine. Fluorine's electronegativity is 3.98. The least electronegative element is francium. Francium's electronegativity is 0.7.

Section Review Answers

Student Textbook page 74

1. Ionic compounds are hard, brittle, crystalline solids with high melting and boiling points that conduct electricity in the liquid phase. They are usually soluble in water, and the aqueous solution also conducts electricity. Examples include sodium chloride, sodium bromide, potassium iodide, and copper(II) sulfate.
2. Covalent compounds are gases, liquids or soft solids with low melting points. They do not conduct electricity as a liquid or in solution. Some are water soluble (e.g. sucrose) some are not (e.g. paraffin wax). Examples are water, carbon dioxide, and ethanol.
3. Students' answers should include the idea that electronegativity is a trend that applies only to atoms involved in bonding. Students should note that, in general, electronegativity increases across a period and decreases down a group. They may note that the trend for electronegativity is essentially the opposite of the trend for atomic size. In other words, the smaller the atom, the greater the electronegativity, in general. This makes sense intuitively, since electrons can get much closer to, and are therefore more attracted to, atoms with small radii. (Note that this is a simplified explanation, but it may help students remember the trend.)
4. **(a)** Li, La, Zn, Si, Br
   (b) Cs, Y, Ga, P, Cl
5. **(a)** $\Delta EN = EN\ \text{O} - EN\ \text{N} = 3.44 - 3.04 = 0.40$, covalent
   (b) $\Delta EN = EN\ \text{O} - EN\ \text{Mn} = 3.44 - 1.55 = 1.89$, ionic
   (c) $\Delta EN = EN\ \text{Cl} - EN\ \text{H} = 3.16 - 2.20 = 0.96$, covalent
   (d) $\Delta EN = EN\ \text{Cl} - EN\ \text{Ca} = 3.16 - 1.00 = 2.16$, ionic.
6. **(a)** The melting point of the unknown solid would be low. Since the compound does not conduct electricity as a liquid, it is a covalent compound. Covalent solids tend to have low melting points.
   (b) As described in the answer to part (a), the compound contains covalent bonds.

Answer to Conclusion Question

5. The reaction is considered physical when the crystal forms. The substance changes phase (or state) from a dissolved form to its solid crystalline form.

Answer to Application Question

6. The seed crystal initiates rapid crystal growth until the liquid in the flask is solid. The contents heat up. The seed crystal allows the excess sodium acetate to come out of the solution by providing a surface to do so. As the ions form bonds, the energy required to dissolve (break the bonds) the solid is released.

Assessment and Evaluation

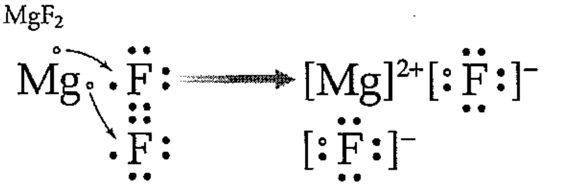
ThoughtLab/ ExpressLab/ Investigation	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Category	Learning Skills
Investigation 3-A: Crystalline Columns, page 80	■ [MCB V.01] demonstrate an understanding of the relationship between periodic tendencies, types of chemical bonding, and the properties of ionic and molecular compounds	■ Rubric for Investigation 3-A (see "Assessment and Evaluation" in the front matter of *Teacher's Resource* CD-ROM)	■ Inquiry	■ Initiative

Section 3.2 p.84

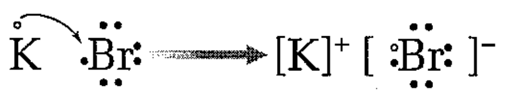
Section Review Answers

Student Textbook page 84

1. (a) MgF_2

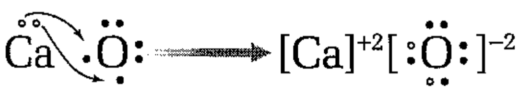


(b) KBr

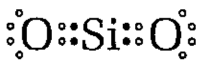


(c) RbCl

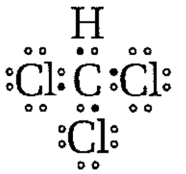
(d) CaO



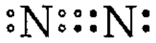
2. (a) SO_2



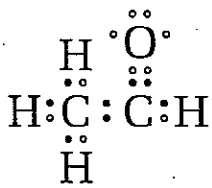
(b) HCl_3



(c) N_2



(d) C_2H_4O



3. (a) $\Delta EN = EN$ O $- EN$ Pd $= 3.44 - 2.20 = 1.24$, covalent
(b) $\Delta EN = EN$ Br $- EN$ C $= 2.96 - 2.55 = 0.41$, covalent
(c) $\Delta EN = EN$ S $- EN$ Ag $= 2.58 - 1.93 = 0.65$, covalent
(d) $\Delta EN = EN$ I $- EN$ Na $= 2.66 - 0.93 = 1.73$, ionic
(e) $\Delta EN = EN$ F $- EN$ Be $= 3.98 - 1.57 = 2.42$, ionic
(f) $\Delta EN = EN$ P $- EN$ Ca $= 2.19 - 1.00 = 1.19$, covalent

4. This statement is true, because in general, the farther away elements are from one another, the greater is the difference in their electronegativity, and the more likely they are to form ionic bonds. Students should note that noble gases are an exception, since they do not participate in ionic bonding.

5. Atoms joined by covalent bonds share electrons to achieve a stable octet. The electrons in these bonds are localized, spending most of their time between the two atoms, and do not move to create a current.

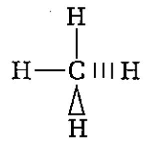
Metallic bonding involves electron sharing, but there are insufficient electrons to make a stable octet for any of the atoms. Metal ions are surrounded by a "sea" of shared valence electrons. The electrons are not localized, as a result, and can therefore carry a current.

6. (a) The ions in an ionic solid are arranged so that the individual ions bond in three dimensions with ions of the opposite charge. The strong electrostatic attraction holds the ions rigidly in position, resulting in a hard crystal that holds its shape.
(b) Ionic solids are not made into tools because:
(i) they dissolve in water, so could not be allowed to get wet;
(ii) they are brittle and shatter easily. A strong blow can shift the ions, so that ions of the same charge are aligned, which causes the crystal to shatter.

Answers to Applications Questions

4. (a) H_2, $\Delta EN = 2.20 - 2.20 = 0$, therefore non-polar
(b) Cl_2, $\Delta EN = 3.16 - 3.16 = 0$, therefore non-polar
(c) H_2O, $\Delta EN = 3.44 - 2.20 = 1.24$; polar bond, angular shape, therefore polar
(d) CO_2, $\Delta EN = 3.44 - 2.55 = 0.89$; therefore polar bond, but symmetrical linear shape, therefore non-polar
(e) NH_3, $\Delta EN = 3.04 - 2.20 = 0.84$; polar bond, pyramidal shape, therefore polar
(f) CCl_4, $\Delta EN = 3.16 - 2.55 = 0.61$; polar bond but tetrahedral shape, therefore non-polar molecule.

5.

Sample molecules	Model	Shape	Polarity
CH_4		tetrahedral	non-polar
HCl	H—Cl	linear	polar
N_2	N≡N	linear	non-polar
O_2	O═O	linear	non-polar

Assessment and Evaluation

ThoughtLab/ ExpressLab/ Investigation	Curriculum Expectations	Assessment Tools/Techniques	Achievement Chart Category	Learning Skills
Investigation 3-B: Modelling Molecules, page 92	*Developing Skills of Inquiry and Communication* ■ [MCB 2.04] Draw Lewis structures, construct molecular models, and give the structural formulae for compounds containing single and multiple bonds	■ Rubric for Investigation 3-B (see "Assessment and Evaluation" in the front matter of *Teacher's Resource* CD-ROM)	■ Inquiry	■ Teamwork ■ Organization

Unit Project Prep

Student Textbook page 94

An abrasive would need to be insoluble in water. Some ionic compounds and minerals have these properties. A window cleaner must dissolve in water, yet also remove oils. It should also evaporate fairly quickly. Ammonia disolves in water, reacts with oil and grease, and evaporates quickly.

Section 3.3

Section Review Answers

Student Textbook page 94

1. (a) B–F, $\Delta EN = EN$ F $- EN$ B $= 3.98 - 2.04 = 1.94$, ionic
(b) C–H, $\Delta EN = EN$ C $- EN$ H $= 2.55 - 2.20 = 0.35$, covalent
(c) Na–Cl, $\Delta EN = EN$ Cl $- EN$ Na $= 3.16 - 0.93 = 2.23$, ionic
(d) Si–O, $\Delta EN = EN$ O $- EN$ Si $= 3.44 - 1.90 = 1.54$, polar covalent
(e) S–O, $\Delta EN = EN$ O $- EN$ S $= 3.44 - 2.58 = 0.86$, polar covalent
(f) C–Cl, $\Delta EN = EN$ Cl $- EN$ C $= 3.16 - 2.55 = 0.61$, polar covalent

2. (d) Δ+ Si–OΔ–
(e) Δ+ S–OΔ–
(f) Δ+ C–ClΔ–

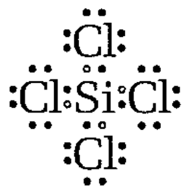
3. A non-polar molecule can have polar bonds if the symmetry of the molecule is such that the polarities of the bonds cancel each other out, e.g., in CO_2 (O=C=O), the two equal but opposite dipoles add to give a net polarity of zero.

4. **(a)** O–F, H–BR, H–Cl, K–Br
   (b) C–H, C–Br, C–O, C–F

5. **(a)** $\Delta EN = 0.54, 0.76, 0.96, 2.14$
   (b) $\Delta EN = 0.35, 0.41, 0.89, 1.43$

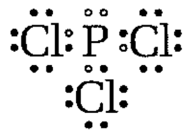
6. Students will respond that chloroform, $CHCl_3$, is polar since all dipoles are not equal, and do not cancel. In methane, CH_4, the polarities of all bonds are equal and thus cancel. As a result, chloroform is slightly polar and the molecules will attract, giving it a higher boiling point than the non-polar methane. A second reason is that with the more massive chlorine atoms present in chloroform, there will be more attraction between the molecules regardless of polarity, e.g. CCl_4 is still a liquid at room temperature. This is, in fact, the more significant effect. **Note:** In early print runs, $CHCl_3$ is incorrectly identified as formaldehyde.

7. **(a)** $SiCl_4$, $\Delta EN + EN$ Cl $- EN$ S $= 1.26$, polar covalent

   The Lewis structure indicates that the molecule is tetrahedral. This means that the bond polarities will cancel, and the molecule is non-polar.

   (b) PCl_3, $\Delta EN = EN$ Cl $- EN$ P $= 1.13$, polar covalent

   The Lewis structure indicates that the molecule is trigonal pyramidal. Therefore, the bond polarities will not cancel, and the molecule will be polar. **Note:** part (c), which appears in the first print run of the text, has been cut from subsequent print runs as the question is too advanced.

8. Accept all reasonable, well-written answers. Students may suggest some of the following possible effects of non-polar water. Under present conditions, water would be a gas, not a liquid, so a different substance would have to be the fluid of life; perhaps a hydrocarbon such as octane, found in gasoline. If temperatures on Earth were such that non-polar water was a liquid, the solid form of water would sink in its liquid instead of floating as ice does. This means that lakes, rivers, ponds, etc. would freeze solid in winter, limiting life as we know it. Aquatic life would have to adapt to survive the winter differently than they do now. Oxygen gas would be less soluble in the fluid of life in the non-polar water world, so a better oxygen absorption mechanism and an efficient metabolism would be required.

or tongues are left, count the pieces to get the formula. For example, a 1+ ion needs only one 1– ion to match (as in NaCl or KNO_3), but two 1+ ions will fit into a 2– ion (as in Na_2O or Li_2SO_4). Three 2– ions are needed to match two 3+ ions, giving formulas such as $Al_2(SO_3)_3$. The positive ions lose electrons so are designed with holes; negative ions gain electrons so are designed with tongues.

- There is no easy way to learn prefixes and suffixes of the polyatomic ions, since the rules are not standard for all the different combinations possible (especially for the oxyanions). The only way to learn these is by memory. Besides drawing up tables for memory learning, try using song methods to enhance the memory-learning processes. Students can set the names and formulas of ions to a favourite song. Limericks are another way to enhance memory learning. As a fun activity, students could be grouped and asked to come up with a song or limerick that covers all the oxyanions of a particular family of anions, such as H–P–O.

Common Misconceptions

- Students may still have their own preconceived ideas of what units constitute an atom, ion, isotope, element, molecule, compound, substance, and matter. They may think that oxygen as an element on the periodic table is the same as naturally occurring oxygen gas, which is in fact a diatomic molecule. Each of these terms should be defined clearly with specific diagrams and examples.
- Students may try to use cation naming systems such as the Stock system to identify anion charges. They may also try to name compounds containing two non-metals using these systems. Finally, they may attempt to name organic compounds using the methods taught in Chapter 3. Ensure students gain enough experience naming compounds and enough feedback on their attempts at naming that they know in which cases to apply specific naming rules.

CHECKPOINT

Student Textbook page 96

The formula for calcium bromide, $CaBr_2$, represents the simplest ratio of calcium ions to bromide ions in a crystal of calcium bromide.

Solutions for Practice Problems

Student Textbook, pages 97, 99, 100, 103, 104, and 105

See *Solutions Manual* for solutions to Practice Problems.

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Section Review Answers

Student Textbook page 106

1. (a) K_2CrO_4, potassium chromate
   (b) NH_4NO_3, ammonium nitrate
   (c) Na_2SO_4, sodium sulfate
   (d) $Sr_3(PO_4)_2$, strontium phosphate
   (e) KNO_2, potassium nitrite
   (f) $Ba(ClO)_2$, barium hypochlorite
2. (a) $MgCl_2$, magnesium chloride
   (b) Na_2O, sodium oxide
   (c) $FeCl_3$, iron(III) chloride or ferric chloride
   (d) CuO, copper(II) chloride or cupric oxide
   (e) ZnS, zinc sulfide
   (f) $AlBr_3$, aluminum bromide
3. (a) sodium hydrogen carbonate, $NaHCO_3$
   (b) potassium dichromate, $K_2Cr_2O_7$
   (c) sodium hypochlorite, NaClO
   (d) lithium hydroxide, LiOH

Unit Project Prep

Student Textbook page 106

Examples of some household cleaning products and the chemicals they contain are as follows: soaps (sodium stearate); toothpaste (sodium lauryl sulfate); window cleaner (ammonia and isopropyl alcohol); chlorine bleach (sodium hydroxide); non-chlorine bleach (sodium perchlorate); detergent (sodium dodecyl sulfate).

(e) potassium permanganate, $KMnO_4$
(f) ammonium chloride, NH_4Cl
(g) calcium phosphate, $Ca_3(PO_4)_2$
(h) sodium thiosulphate, $Na_2S_2O_3$

4. (a) VO, vanadium(II) oxide
VO_2, vanadium(IV) oxide
V_2O_3, vanadium(III) oxide
V_2O_5, vanadium(V) oxide
(b) FeS, iron(II) sulfide, ferrous sulfide
Fe_2S_3, iron(III) sulfide, ferric sulfide
(c) NiO, nickel(II) oxide, nickelous oxide
Ni_2O_3, nickel(III) oxide, nickelic oxide

5. The oxide ion is O^{2-}, thus the peroxide ion is O_2^{2-}, which is a polyatomic ion. The formula of the polyatomic ion must be kept intact when writing formulas. Therefore, hydrogen peroxide's formula must be written as H_2O_2 and not HO.

End of chapter review.

Chapter 3 Review Answers

Student Textbook pages 29–31

Answers to Knowledge/Understanding Questions

1. Electron affinity is an actual measure of the energy released or absorbed by an atom when an electron is added to the atom to form a negative ion. Electronegativity is a number, derived from a formula that includes factors such as electron affinity and ionization potential, that indicates an element's ability to attract electrons within a chemical bond.

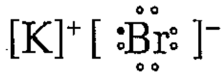
2. (a) Zn–O, $\Delta EN = EN\ \text{O} - EN\ \text{Zn} = 3.44 - 1.65 = 1.79$
(b) Mg–I, $\Delta EN = EN\ \text{I} - EN\ \text{Mg} = 2.66 - 1.31 = 1.35$
(c) Co–Cl, $\Delta EN = EN\ \text{Cl} - EN\ \text{Co} = 3.16 - 1.88 = 1.28$
(d) N–O, $\Delta EN = EN\ \text{O} - EN\ \text{N} = 3.44 - 3.04 = 0.40$

3. (a) ionic
(b) polar covalent
(c) polar covalent
(d) covalent

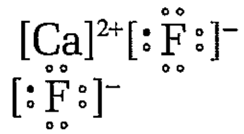
4. Covalent compounds have low melting and boiling points; are soft solids, gases, or liquids at room temperature; do not conduct electricity in solution or in liquid state; and may or may not be soluble in water.
Ionic compounds have high melting and boiling points; are hard, brittle crystalline solids at room temperature; conduct electricity in the liquid state and in solution; and are usually soluble in water.

5. Examples of ionic compounds include sodium chloride, potassium iodide, and calcium chloride. Examples of covalent compounds include water, carbon dioxide, and sucrose.

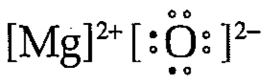
6. Noble gases are unreactive, and most have eight electrons in the valence shell (helium has two). Other elements tend to react so that they attain eight electrons in their valence electron energy level, by gaining, losing, or sharing electrons.

7. **(a)** 

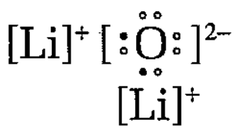
potassium bromide

(b) 

calcium fluoride

(c) 

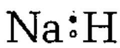
magnesium oxide

(d) 

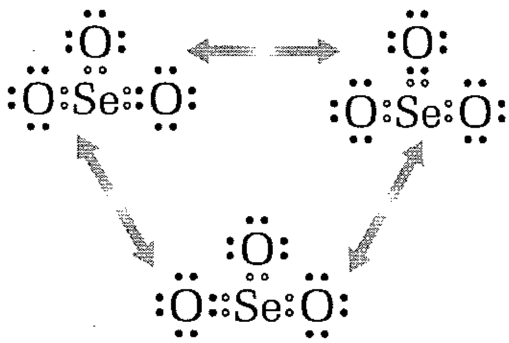
lithium oxide

8. **(a)** SiO_2 **Note:** SiO_2 in nature is a network solid with single Si-O bonds holding the entire crystal together. The mineral is called quartz. Students will answer as follows, however:

(b) NaH

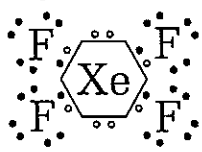


(c) SeO_3 **Note:** this molecule involves resonance structures. Accept any of these answers from students. They will probably need help with this question.

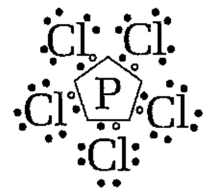


(d) NF_3

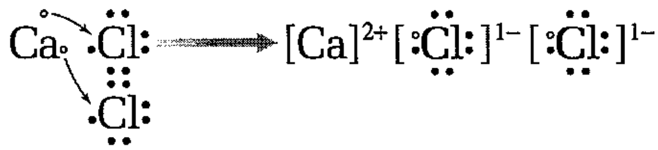
(e) XeF_4 **Note:** this is an exception to the octet rule.



(f) PCl_5 **Note:** this is an exception to the octet rule.



9. The two electrons transfer, one each to two chlorine atoms forming a calcium ion with a +2 charge and two chloride ions with a −1 charge, resulting in a compound, $CaCl_2$.



10. Oxygen, nitrogen and chlorine are gases at room temperature, because they are held together by pure covalent bonds (O=O, N≡N, Cl–Cl). There is little attraction between the molecules because there are no dipoles, thus the molecules remain separate and the elements are gases. Another factor that contributes is the fact that the elements are relatively light, compared to iodine, for example.
11. Ionic compounds do not contain molecules, since one ion is bound to several other ions of opposite charge in a lattice. To speak of intermolecular forces in ionic compounds is to imply the existence of molecules in the compounds. It would be better to speak of forces between the ions or interionic forces.
12. A covalent bond exists between atoms of the same or almost the same electronegativity. This means that the shared electrons are shared essentially equally between the atoms involved in the bond. In a polar covalent bond, one atom attracts the electrons of the bond more strongly than the other. This results in a charge separation and one side of the bond is more negatively charged than the other, hence a dipole is created across the bond. In terms of electronegativity difference, ΔEN of 0.5 or less indicates a non-polar covalent bond.
13. Atoms joined by an ionic bond have a large electronegativity difference, so that it can be said that one electron (or more) has been transferred from one atom to the other, resulting in the formation of a positive and a negative ion. A polar covalent bond has an electronegativity difference that is large, but the electrons are still thought of as shared; a dipole across the bond results.
A ΔEN of 1.7 or greater results in an ionic bond, a ΔEN between 0.5 and 1.7 results in a polar covalent bond.
14. (a) Mn–N, $\Delta EN = 1.49$; Mn–O, $\Delta EN = 1.89$; Mn–F, $\Delta EN = 2.43$; most polar
(b) Be–Br, $\Delta EN = 1.39$; Be–Cl, $\Delta EN = 1.59$; Be–F, $\Delta EN = 2.41$
(c) Ag–Cl, $\Delta EN = 1.23$; Hg–Cl, $\Delta EN = 1.26$; Cu–Cl, $\Delta EN = 1.26$; Fe–Cl, $\Delta EN = 1.33$; Ti–Cl, $\Delta EN = 1.62$
15. (a) a Lewis structure
(b) a ball and stick model or a space-filling model
(c) a Lewis structure
(d) a ball and stick model or a space-filling model
16.

(a) AgCl	Ag^{1+}	Cl^{1-}
(b) Mn_3P_2	Mn^2	P^3
(c) PCl_5	P^5	Cl^1
(d) CH_4	C^4	H^1
(e) TiO_2	Ti^{4+}	O^{2-}

(f) HgF_2	Hg^{2+}	F^{1-}
(g) CaO	Ca^{2+}	O^{2-}
(h) Fe_2S	Fe^2	S^4

17. **(a)** tin(II) fluoride, SnF_2
(b) barium sulfate, $BaSO_4$
(c) hydrogen cyanide, HCN
(d) cesium bromide, CsBr
(e) ammonium hydrogen phosphate, $(NH_4)_2HPO_4$
(f) sodium periodate, $NaIO_4$
(h) potassium bromate, $KBrO_3$
(i) sodium cyanate, NaCNO

18. **(a)** HIO_2, hydrogen iodite (iodous acid)
(b) $KClO_4$, potassium perchlorate
(c) CsF, cesium flouride
(d) $NiCl_2$, nickel(II)chloride, nickelous chloride
(e) $NaHSO_4$, sodium hydrogen sulfate
(f) $Al_2(SO_3)_3$, aluminum sulfite
(g) $K_2Cr_2O_7$, potassium dichromate
(h) $Fe(IO_4)_3$, iron(III)periodate, ferric periodate

19. **(a)** FeO, iron(II) oxide, ferrous oxide
(b) $SnCl_4$, tin(IV) chloride, stannic chloride
(c) $CuCl_2$, copper(II) chloride, cupric chloride
(d) $CrBr_3$, chromium(III) bromide, chromic bromide
(e) PbO_2, lead(IV) oxide, plumbic oxide
(f) HgO, mercury(II) oxide, mercuric oxide

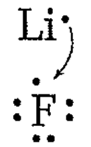
Inquiry

20. Take the melting point of each substance. The ionic compound should have the higher melting point. Test the electrical conductivity of the melted substance. The ionic material should conduct, the covalent material will not. Test the solubility of the materials in water. If they dissolve in water, test the conductivity of the solution. The ionic
material will conduct electricity in solution, the covalent material will not.

21. Liquid A is polar, since it will move towards a charged rod indicating an opposite charge on one end of the molecule. Liquid B is non-polar since it is unaffected by a charged pod.

Communication

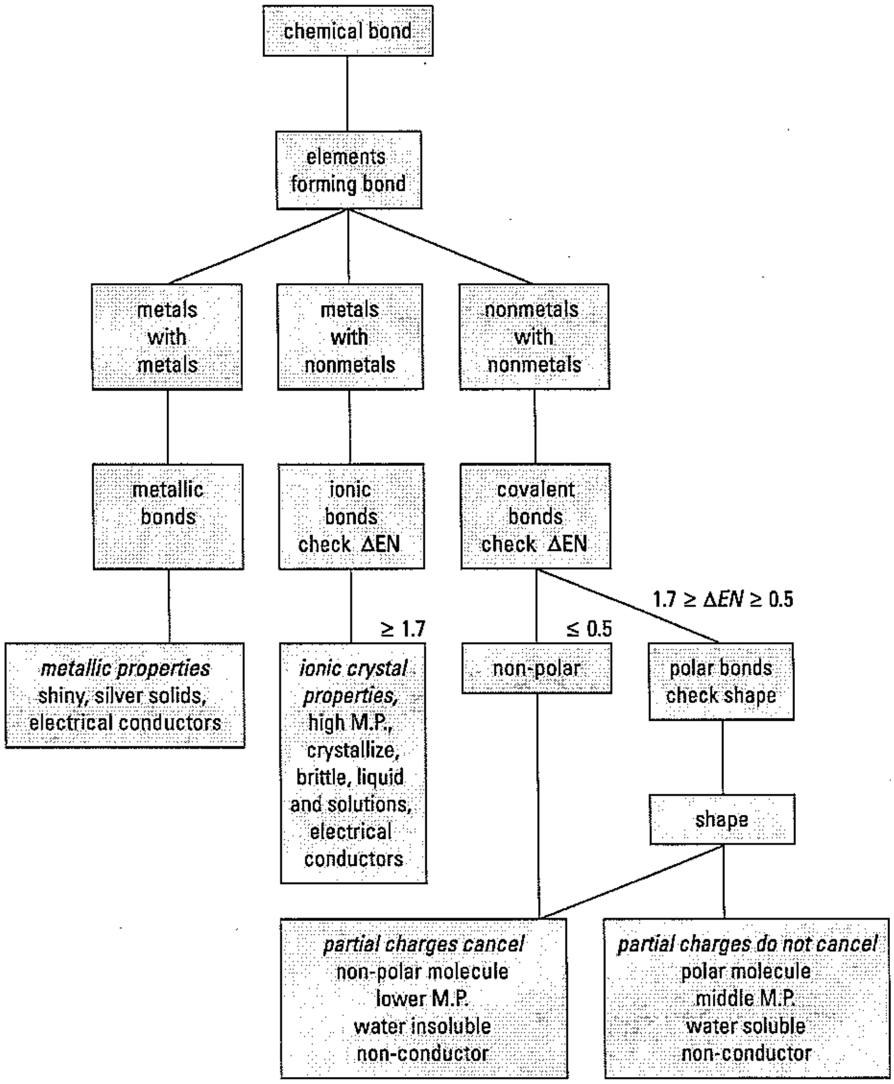
22. Students may answer that the numbers of electrons lost or gained to obtain a noble gas valence shell becomes the valence of the element.



loses 1 electron ∴ valence = +1

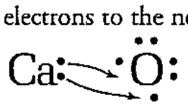
gains 1 electron ∴ valence = −1

23. Students may create a concept map like the one shown below:



24. Metallic bonds consist of shared electrons, but there are insufficient electrons to fill the valence shell. Hence adding a different metal in any proportion does not disrupt the bonding. No definite ratio need therefore apply to bonding one metal to another. The metal's electrons are very mobile and solid metals can conduct electricity.

Metals bond to non-metals in specific ratios since the non-metal gains a specific number of electrons from the metal, and the metal gives up a specific number of electrons to the non-metal.



Calcium and oxygen bond to give a specific atomic ratio and formula (CaO) to the resulting ionic compound. The ionic solid has its electrons localized to specific ions, so the electrons cannot move to conduct electricity.

25. The chemical language system is a universal language. i.e., chemists from all over the world speak the same chemical language. To maintain this universality, chemists worldwide must agree on the naming system.

Answer to Making Connections Question

26. The naming of the elements goes to the group credited with the discovery (in this case the nuclear synthesis and isolation) of the element. Groups all over the world are trying to discover new elements. When they think that a new element has been discovered, they propose a name. If more than one group thinks they have made the discovery close to the same time, a group of scientists looks at the evidence to see which group is granted priority and the chance to name the element.The elements 104–109 are named for famous scientists e.g., 104, Ernest Rutherford. 104 Rf (Rutherfordium), 105 Db (Dubnium), 106 Sg (Seaborgium), 107Bh (Bohrium), 108 Hs (Hassium), 109 Mt (Meitnerium). Students should discuss whether they believe this system is fair. Some may feel the naming of elements should be systematic. Accept all reasoned and reasonable answers.