Chapter 2: Chemical Compounds and Bonding

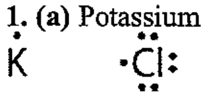
Mini Investigation: Fun with Teflon Tape, page 55

A. MSDS warnings include statements such as "Above 250 °C, some decomposition of polytetrafluoroethylene products can be expected with evolution of gaseous and particulate products, which are toxic if inhaled. This can give rise to a characteristic syndrome with influenza-type symptoms known as 'polymer fume fever'."
B. The tape did not undergo any changes in water but it dissolved slightly in oil. This indicates that PTFE and oil have some type of similar property.
C. Answers may vary. Sample answer: PTFE is so useful because it is waxy, flexible, and extremely slippery.
D. Answers may vary. Sample answer: PTFE is a useful material for the lining of containers (beverage containers, industrial vessels, laboratory equipment). It is an excellent electrical insulator, so it can be used to wrap cables and wires. Due to its flexibility, it can be moulded into complex shapes.
E. PTFE does not degrade naturally (or it degrades very slowly). It can thus be placed safely in landfills; however, it will add to the landfill burden indefinitely.

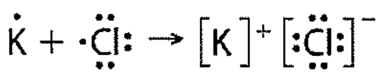
Section 2.1: Ionic Compounds

Tutorial 1 Practice, page 58

1. (a) Potassium chloride:



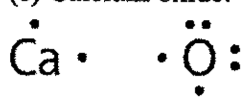
One K atom is needed for every Cl atom.



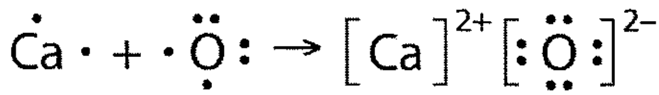
The chemical formula for potassium chloride is KCl.
(b) Calcium chloride:

Two Cl atoms are needed for every Ca atom.

The chemical formula for calcium chloride is $CaCl_2$.
(c) Calcium oxide:



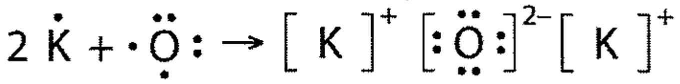
One Ca atom is needed for every O atom.



The chemical formula for calcium oxide is CaO.

(d) Potassium oxide:

Two K atoms are needed for every O atom.



The chemical formula for potassium oxide is K_2O.

Section 2.1 Questions, page 60

1. Three distinctive physical properties of ionic compounds are a high melting and boiling point, brittleness, and conductivity when dissolved in water.

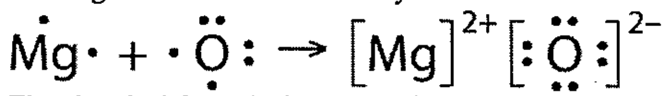
2. An electrolyte is a compound that dissolves in water, producing a solution that conducts electricity.

An ionic bond is the electrostatic force of attraction between a positive ion and a negative ion – a type of chemical bond.

A formula unit is the smallest repeating unit in an ionic crystal.

3.

One Mg atom is needed for every O atom.



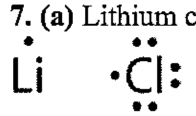
The chemical formula for magnesium oxide is MgO.

4. Pure water is a poor conductor of electricity because H_2O is a molecular compound. There are no charged particles to help with the flow of electricity. Tap water is a fair conductor of electricity because tap water contains many dissolved ions, which allow for the passage of electricity.

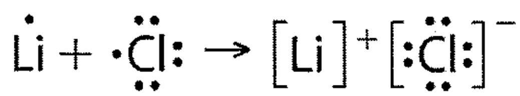
5. The magnitude of the charge of the ions within an ionic compound has an effect on the strength of the ionic bond. Magnesium oxide, which has ionic bonds between Mg^{2+} and O^{2-} ions, has a greater force of attraction than the other ionic compounds listed because the charge of the ions involved is greater. For example, sodium chloride has ionic bonds between the Na^+ and Cl^- ions. As well, the size of the ions can influence the strength of the ionic bond. In general, the smaller the ionic radius, the greater the force of attraction between the ions.

6. The strong ionic bonds will keep ionic compounds in the solid state at ambient temperatures. When the ionic crystal structure is offset, this may result in ions with like charges being side by side, and consequently the repelling forces of like charges will shatter the compound.

7. (a) Lithium chloride:



One Li atom is needed for every Cl atom.



The chemical formula for lithium chloride is LiCl.

(b) Magnesium chloride:

One Mg atom is needed for every two Cl atoms.

The chemical formula for magnesium chloride is $MgCl_2$.

(c) Sodium sulfide:

Two Na atoms are needed for every S atom.

The chemical formula for sodium sulfide is Na_2S.

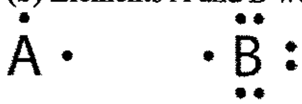
(d) Aluminum oxide:

Two Al atoms are needed for every 3 O atoms.

The chemical formula for aluminum oxide is Al_2O_3.

8. (a) Element A with 2 valence electrons is most likely a metal. Element B with 7 valence electrons is a non-metal.

(b) Elements A and B would form a compound as follows:



Two B atoms are needed for every A atom.

(c) An ionic compound is formed.

(d) The chemical formula for this compound is AB_2.

9. Ionic compounds, houndstooth check fabrics, and the work of M.C. Escher all have repeating units or formula units.

10. Answers may vary based on research. Sample answer: Sodium chloride, NaCl, is the most common road salt. Sodium chloride is inexpensive but it is not an effective de-icer at low temperatures. It also damages cars and concrete, poisons the soil, and can kill plants and harm pets. Sodium contamination of drinking water supplies can have negative impacts on humans. Calcium chloride works at very low temperatures and isn't as damaging to soil and plants as sodium chloride, but it costs a bit more and is corrosive to metal and concrete. Calcium magnesium acetate does not cause corrosion, is safe for concrete and plants, but is only good down to the same temperature as sodium chloride. It is better at preventing water from re-freezing than at melting snow and ice. Potassium acetate is a less-toxic, biodegradable alternative that works at colder temperatures than either calcium magnesium acetate or sodium chloride.

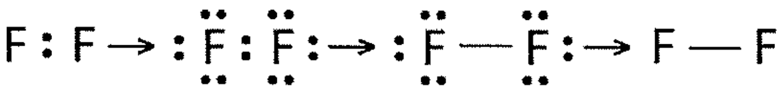
Section 2.2: Molecular Elements and Compounds

Tutorial 1 Practice, pages 65 and 67

1. (a) F_2:

F F

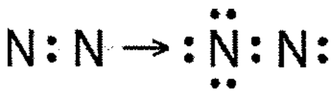
2 F atoms: 2 (7 e^-) = 14 e^-



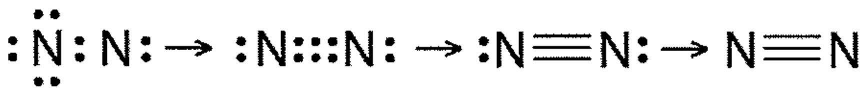
(b) N_2:

N N

2 N atoms: 2 (5 e^-) = 10 e^-

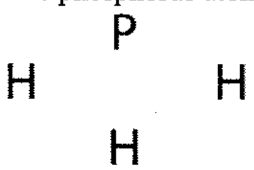


No electrons remain.

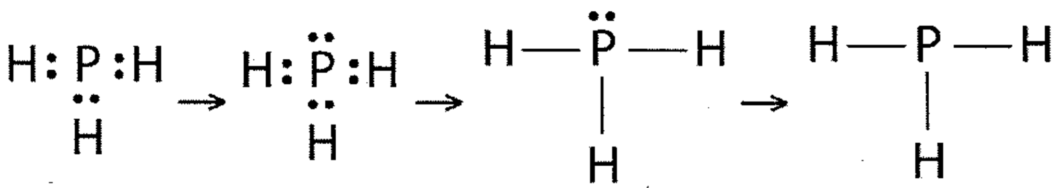


(c) PH_3:

The phosphorus atom has the largest bonding capacity, 3. Each hydrogen atom can form 1 bond.



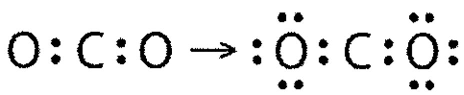
P atom: 5 e^-
3 H atoms: 3 (1 e^-) = 3 e^-
Total: 8 e^-



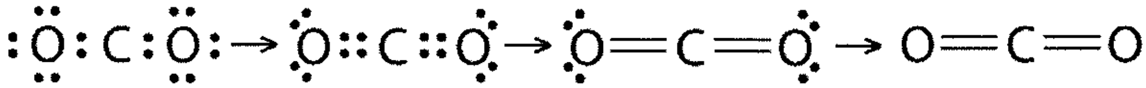
(d) CO_2:

O C O

C atom: 4 e^-
2 O atoms: 2 (6 e^-) = 12 e^-
Total: 16 e^-

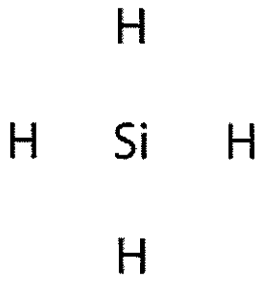


No electrons remain, but the carbon atom needs 2 more pairs to satisfy the octet rule.

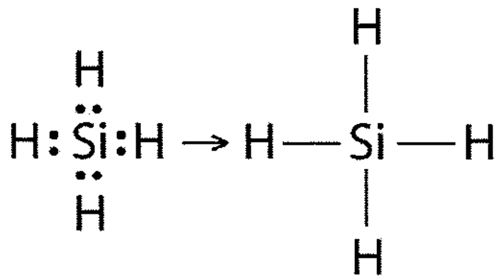


(e) SiH_4:

The silicon atom has the largest bonding capacity, 4. Each hydrogen atom can form 1 bond.

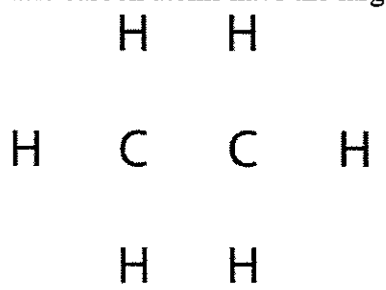


Si atom: 4 e⁻
4 H atoms: 4 (1 e⁻) = 4 e⁻
Total: 8 e⁻

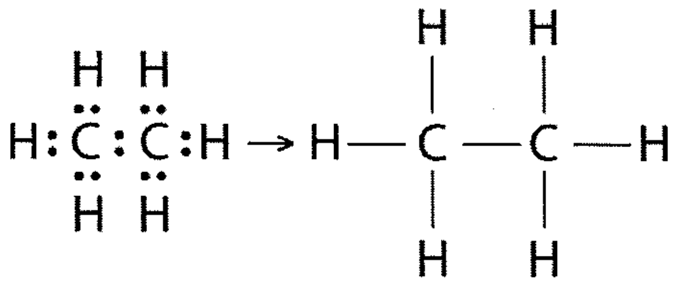


(f) C_2H_6:

The carbon atoms have the largest bonding capacity, 4. Each hydrogen atom can form 1 bond.

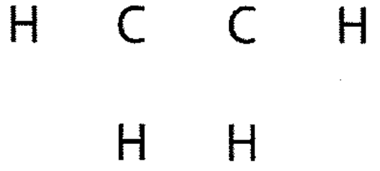


2 C atoms: 2 (4 e⁻) = 8 e⁻
6 H atoms: 6 (1 e⁻) = 6 e⁻
Total: 14 e⁻

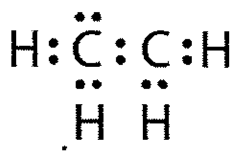


(g) C_2H_4:

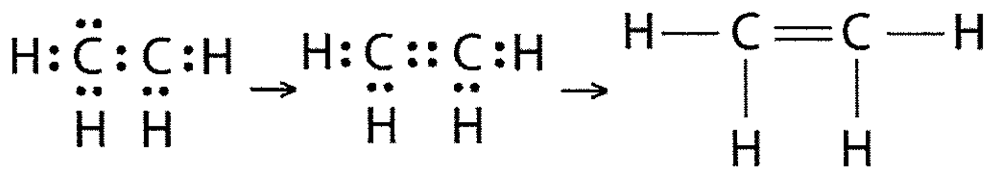
The carbon atoms have the largest bonding capacity, 4. Each hydrogen atom can form 1 bond.



2 C atoms: 2 (4 e^-) = 8 e^-
4 H atoms: 4 (1 e^-) = 4 e^-
Total: 12 e^-



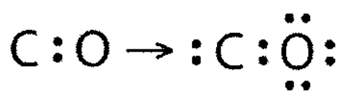
No electrons remain, but one carbon atom still needs another pair to satisfy the octet rule.



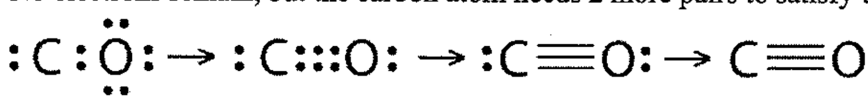
(h) CO:

C O

C atom: 4 e^-
O atom: 6 e^-
Total: 10 e^-



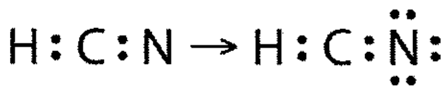
No electrons remain, but the carbon atom needs 2 more pairs to satisfy the octet rule.



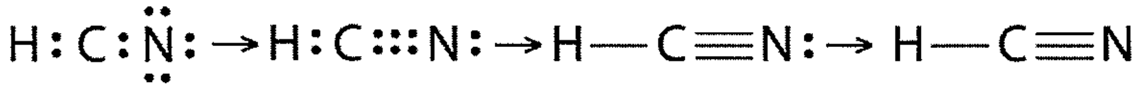
(i) HCN:
The carbon atom has the largest bonding capacity.

H C N

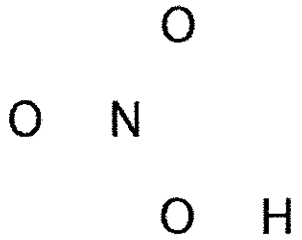
H atom: 1 e^-
C atom: 4 e^-
N atom: 5 e^-
Total: 10 e^-



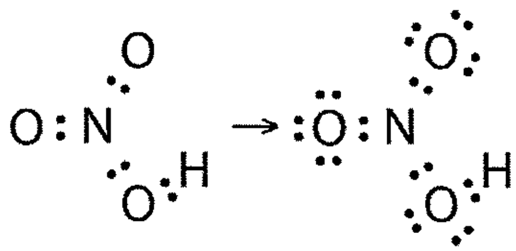
No electrons remain, but the carbon atom needs 2 more pairs to satisfy the octet rule.



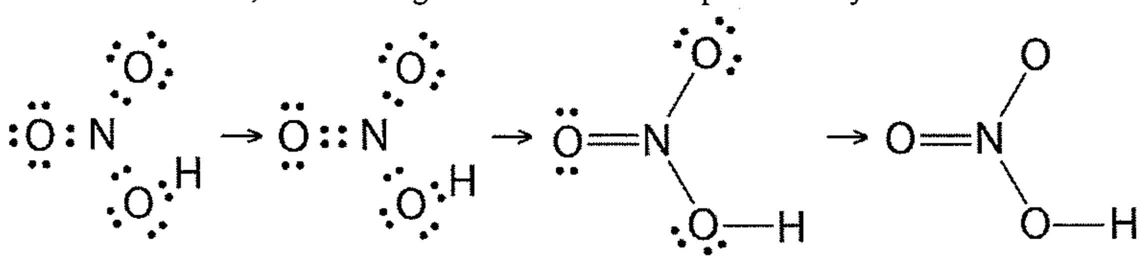
(j) HNO_3:
The bonding capacities are: nitrogen, 3; oxygen, 2; and hydrogen, 1.



H atom: 1 e^-
N atom: 5 e^-
3 O atoms: 3 (6 e^-) = 18 e^-
Total: 24 e^-

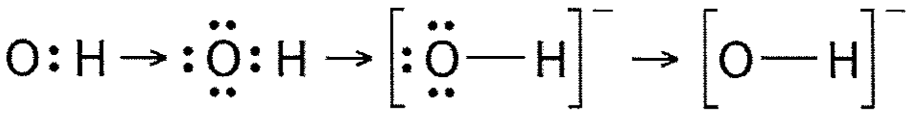


No electrons remain, but the nitrogen atom needs another pair to satisfy the octet rule.



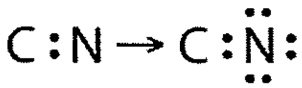
2. (a) OH^-:

O atom: 6 e^-
H atom: 1 e^-
–1 charge of OH^-: 1 e^-
Total: 8 e^-

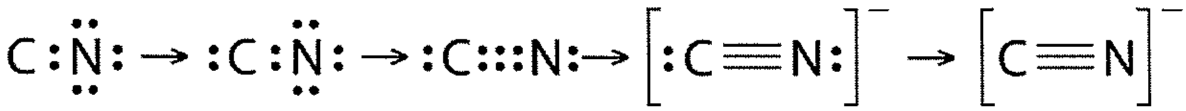


(b) CN^-:

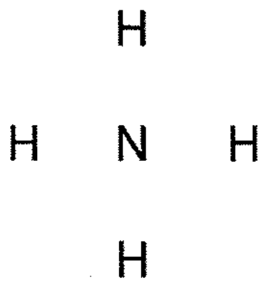
C atom: 4 e^-
N atom: 5 e^-
–1 charge of CN^-: 1 e^-
Total: 10 e^-



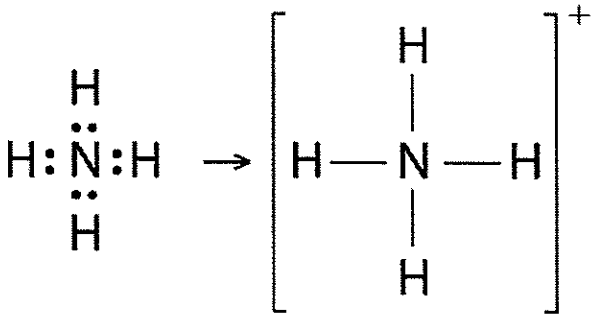
(10 e^-) – (8 e^-) = 2 e^-



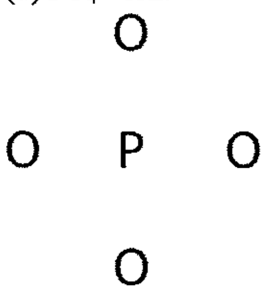
(c) NH_4^+:



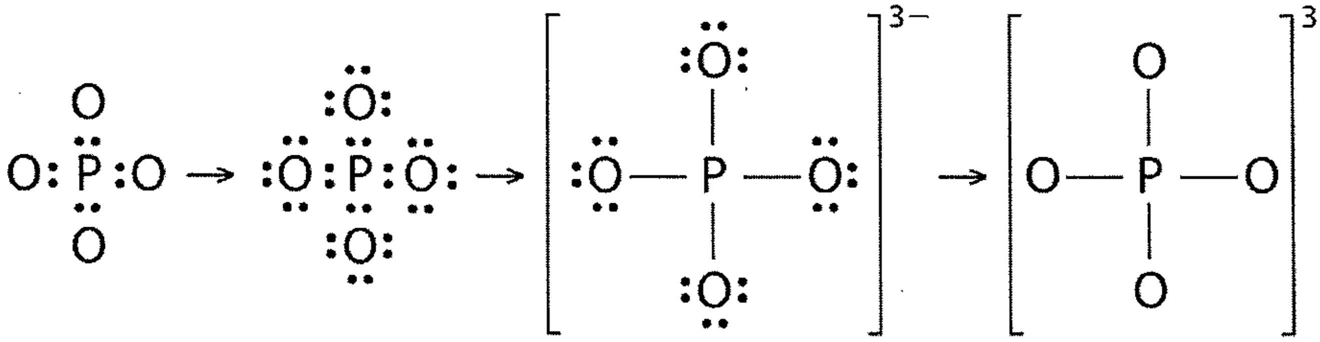
N atom: 5 e^-
4 H atoms: 4 (1 e^-) = 4 e^-
+1 charge of NH_4^+: –(1 e^-)
Total: 8 e^-



(d) PO_4^{3-} ion:

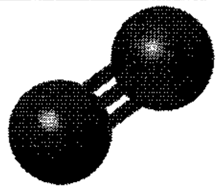
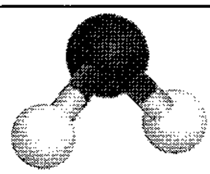
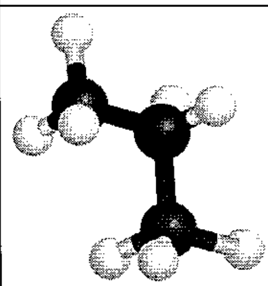
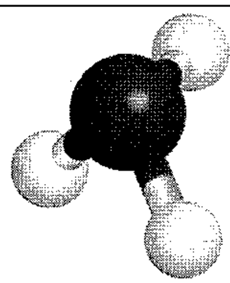


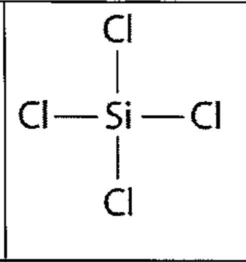
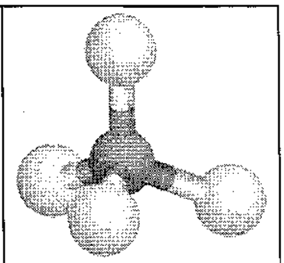
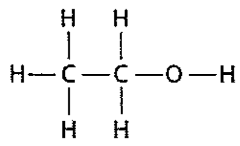
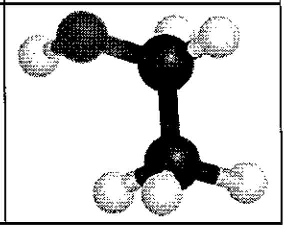
P atom: 5 e^-
4 O atoms: 4 (6 e^-) = 24 e^-
–3 charge of PO_4^{3-}: 3 e^-
Total: 32 e^-



Mini Investigation: Building Molecular Models, page 67

A. Selected Molecular Substances

Chemical name	Chemical formula	Structural formula of molecule	Number of single covalent bonds	Number of double or triple covalent bonds	Number of lone pairs around each atom	Sketch of molecular shape
nitrogen	N_2	N≡N	0	1 triple	1 for each N	
water	H_2O	H—O—H	2	0	2 for O; none for H's	
carbon dioxide	CO_2	O=C=O	0	2 double	2 for each O; none for C	
propane	C_3H_8	H H H │ │ │ H—C—C—C—H │ │ │ H H H	10	0	none	
ammonia	NH_3	H—N—H │ H	3	0	1 for N; none for H's	

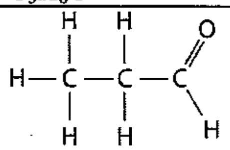
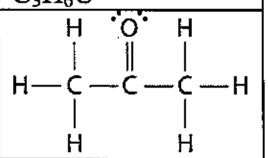
silicon tetrachloride	$SiCl_4$		4	0	3 for each Cl; none for Si	
ethanol	C_2H_5OH		8	0	2 for O; none for C's and H's	

B. Answers may vary. Sample answer: Building molecular models allows you to visualize molecules in three-dimensions. Molecular structures do not look like they do on paper, and a modelling kit forces you to build molecules in their natural shapes. You can pick up the model and hold it, rotate parts of the molecule around bonds, and look for symmetry. You can put two models together to see how a compound is formed.

C. Answers may vary. Sample answer: The oxygen molecule, O_2, will be diatomic like the nitrogen molecule, N_2, and methane, CH_4, will have a similar structural formula and molecular shape to silicon tetrachloride, $SiCl_4$.

D. Answers may vary. Sample answer:

Comparison of Propanol and Acetone

	Propanol	**Acetone**
Chemical formula	C_3H_6O	C_3H_6O
Structural formula		
Melting point	–81 °C	–95 °C
Boiling point	49 °C	56 °C
Appearance	colourless liquid	colourless liquid
Main use	solvent	solvent

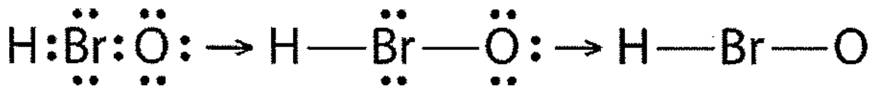
Section 2.2 Questions, page 69

1. Three distinctive physical properties of molecular compounds are relatively low boiling and melting points, poor conductivity when dissolved in water (for most), and solids can be soft, waxy, flexible, or crystalline.

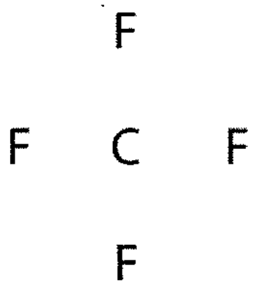
2. (a) HBrO(l):

H Br O

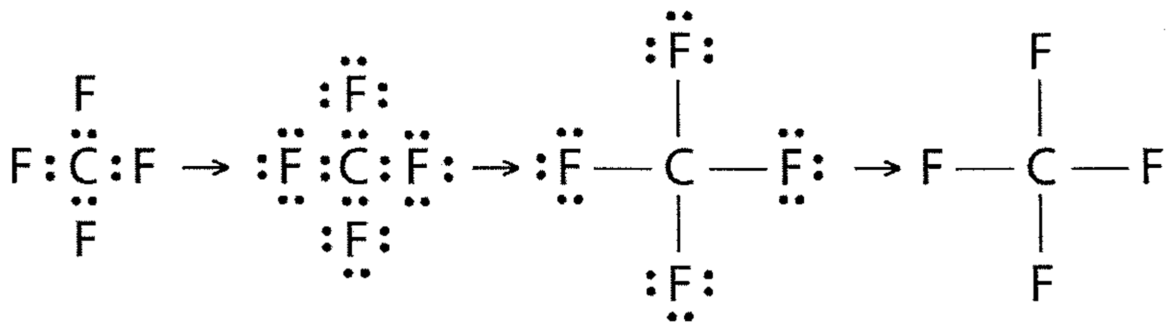
H atom: 1 e^-
Br atom: 7 e^-
O atom: 6 e^-
Total: 14 e^-



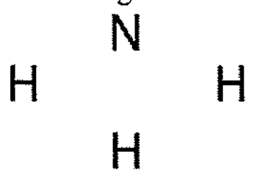
(b) CF_4(l):
The carbon atom has the largest bonding capacity, 4. Each fluorine atom can form 1 bond.



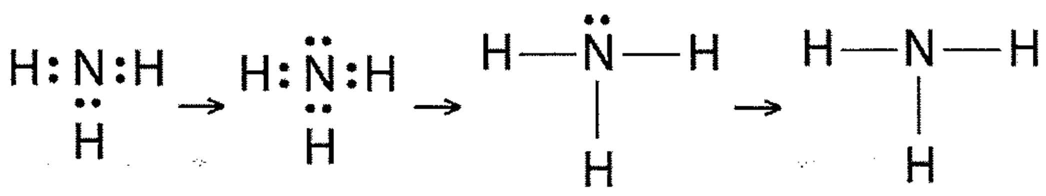
C atom: 4 e^-
4 F atoms: 4 (7 e^-) = 28 e^-
Total: 32 e^-



(c) $NH_3(g)$:
The nitrogen atom has the largest bonding capacity.

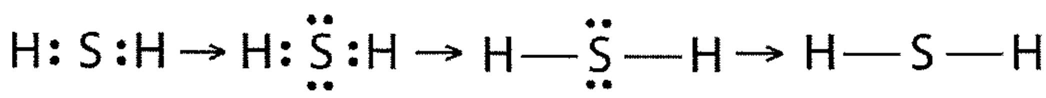


N atom: 5 e^-
3 H atoms: 3 (1 e^-) = 3 e^-
Total: 8 e^-



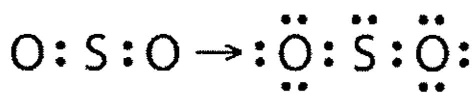
(d) $H_2S(g)$:

S atom: 6 e^-
2 H atoms: 2 (1 e^-) = 2 e^-
Total: 8 e^-

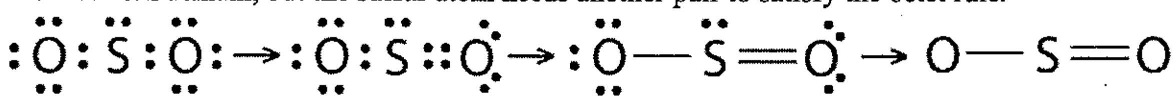


(e) $SO_2(g)$:
Sulfur and oxygen have the same bonding capacity.

S atom: 6 e^-
2 O atoms: 2 (6 e^-) = 12 e^-
Total: 18 e^-

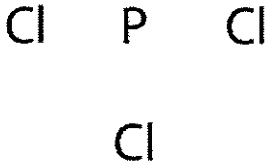


No electrons remain, but the sulfur atom needs another pair to satisfy the octet rule.

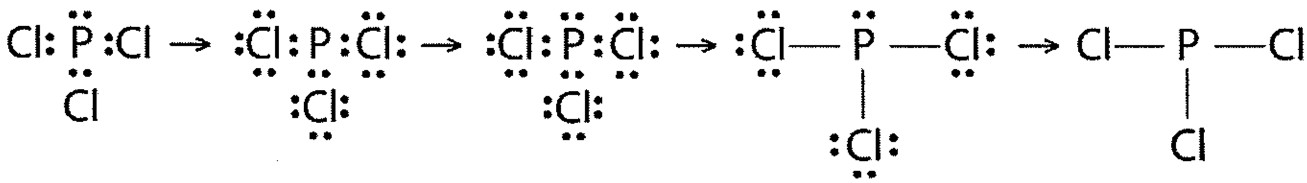


(f) $PCl_3(g)$:

The phosphorus atom has the largest bonding capacity, 3. Each chlorine atom can form 1 bond.



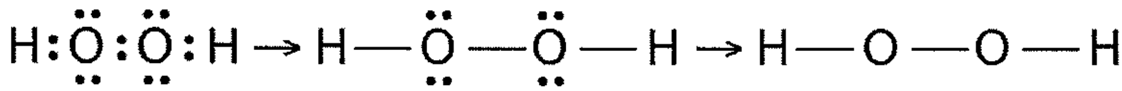
P atom: 5 e^-
3 Cl atoms: 3 (7 e^-) = 21 e^-
Total: 26 e^-



(g) $H_2O_2(l)$:

H O O H

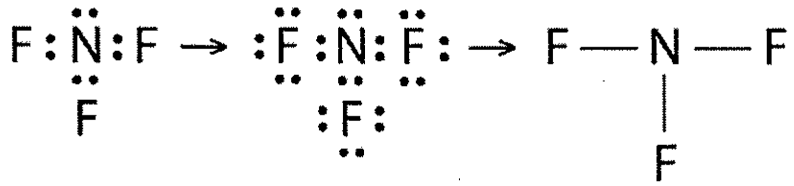
O atom: 2(6 e^-) = 12 e^-
H atom: 2(1 e^-) = 2 e^-
Total: 14 e^-



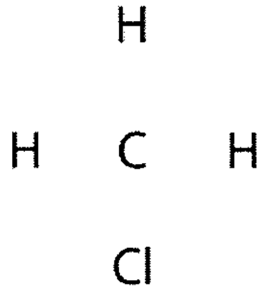
(h) $NF_3(g)$

The nitrogen atom has the largest bonding capacity, 5. The fluorine atoms can form 1 bond.

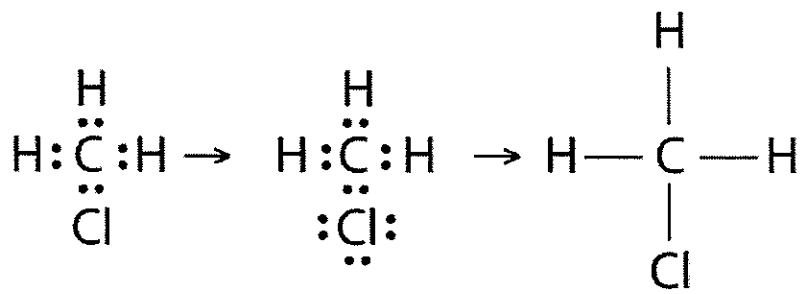
N atom: 5 e^- = 5 e^-
F atom: 3(7 e^-) = 21 e^-
Total: 26 e^-



(i) $CH_3Cl(g)$:
The carbon atom has the largest bonding capacity, 4. The hydrogen and chlorine atoms can each form 1 bond.

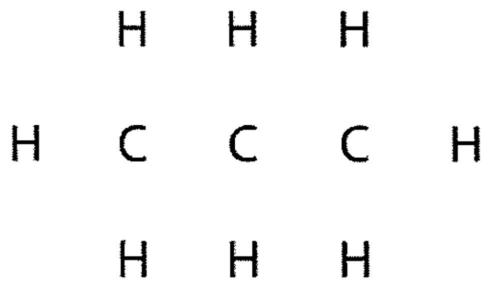


C atom: 4 e^-
3 H atoms: 3 (1 e^-) = 3 e^-
Cl atom: 7 e^-
Total: 14 e^-

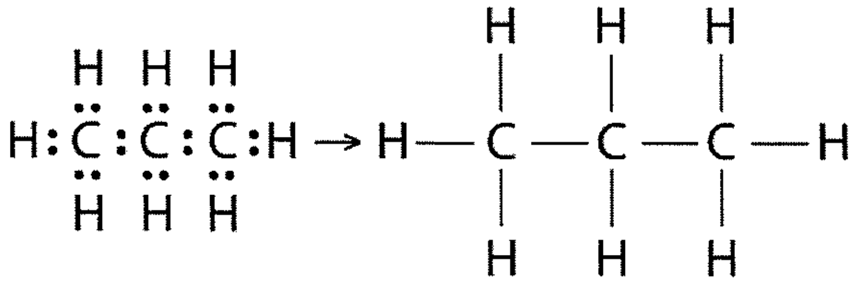


(j) $C_3H_8(g)$:

The carbon atoms have the largest bonding capacity, 4. The hydrogen atoms can each form 1 bond.



3 C atoms: 3 (4 e^-) = 12 e^-
8 H atoms: 8 (1 e^-) = 8 e^-
Total: 20 e^-



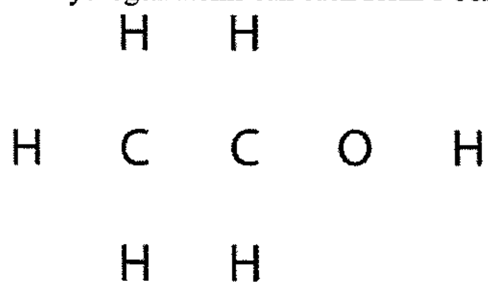
(k) $C_2H_2(g)$:
The carbon atoms have the largest bonding capacity. The hydrogen atoms can each form 1 bond.

H C C H

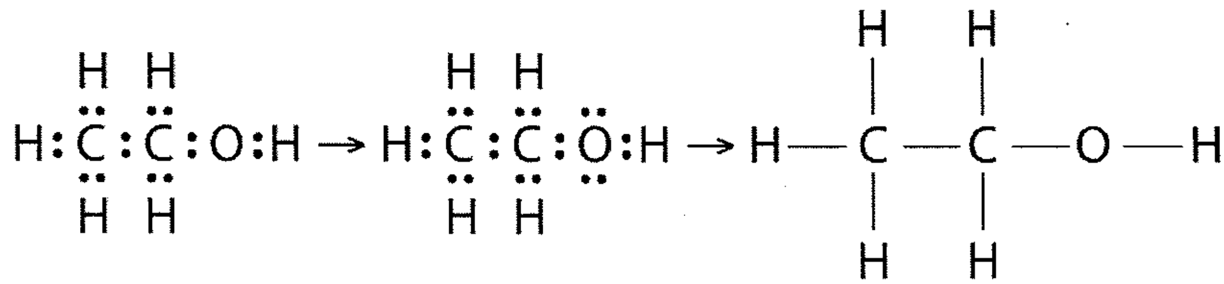
2 C atoms: 2 (4 e^-) = 8 e^-
2 H atoms: 2 (1 e^-) = 2 e^-
Total: 10 e^-

No electrons remain, but the second carbon atom needs 2 more pairs to satisfy the octet rule.

(l) $C_2H_5OH(l)$:
The carbon atoms have the largest bonding capacity, 4. The oxygen atom can form 2 bonds, and the hydrogen atoms can each form 1 bond.



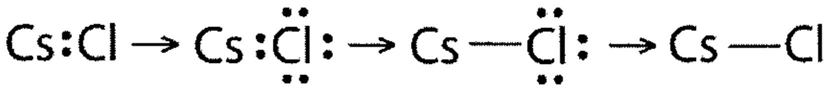
2 C atoms: 2 (4 e^-) = 8 e^-
O atom: 6 e^-
6 H atoms: 6 (1 e^-) = 6 e^-
Total: 20 e^-



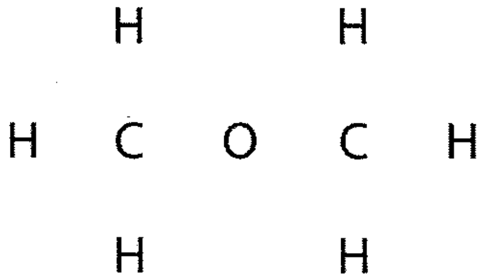
(m) CsCl(s):

Cs   Cl

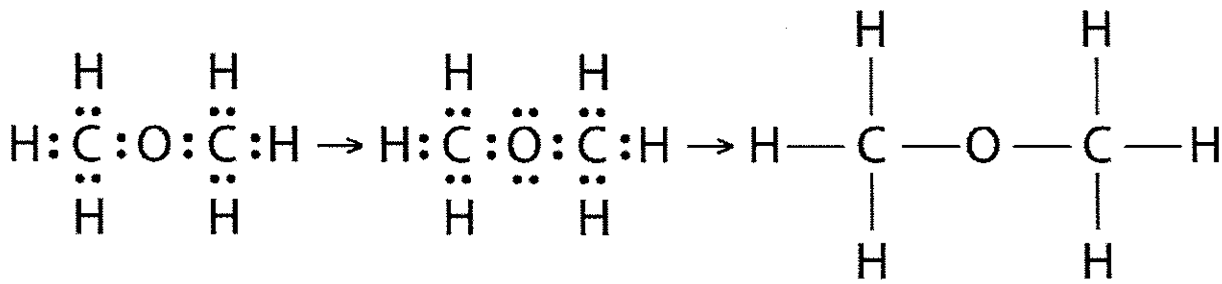
Cs atom: 1 e$^-$
Cl atoms: 7 e$^-$ = 7 e$^-$
Total: 8 e$^-$



(n) CH_3OCH_3(g):
The carbon atoms have the largest bonding capacity, 4. The oxygen atom can form 2 bonds, and the hydrogen atoms can each form 1 bond.

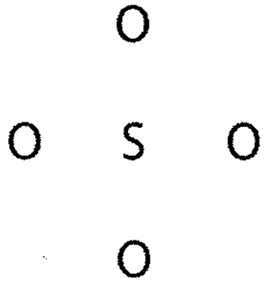


2 C atoms: 2 (4 e$^-$) = 8 e$^-$
O atom: 6 e$^-$
6 H atoms: 6 (1 e$^-$) = 6 e$^-$
Total: 20 e$^-$

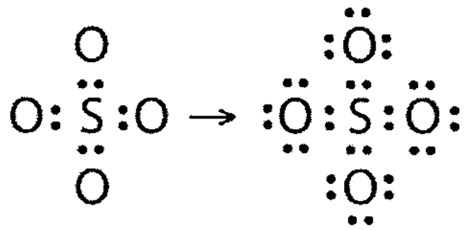


3. The compounds in Question 2 that contain multiple (double or triple) bonds are CO and C_2H_2.

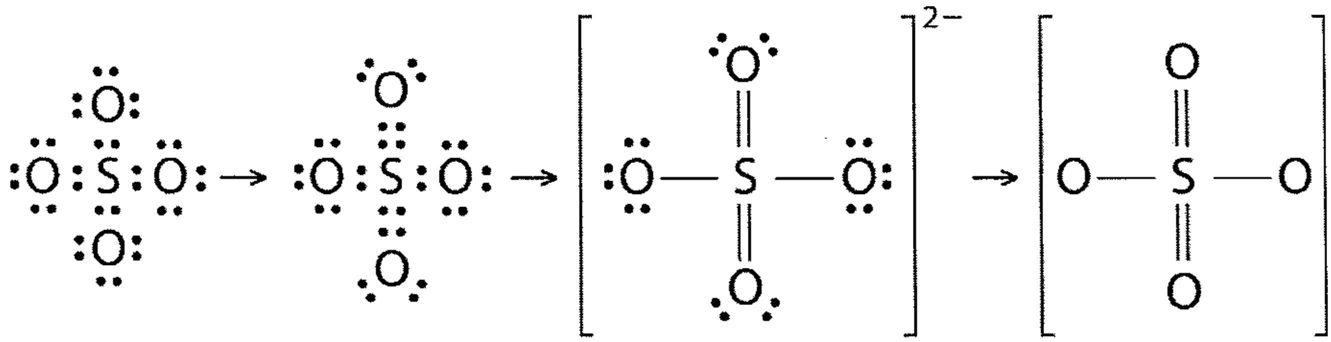
4. Lewis structure and structural formula for polyatomic ion:
(a) SO_2^{2-}:
The sulfur atom has the largest bonding capacity, 6. The oxygen atoms can each form 2 bonds.



S atom: 6e^-
4 O atoms: 4(6 e^-) = 24 e^-
–2 charge of SO_4^{2-}: 2 e^-
Total: 32 e^-

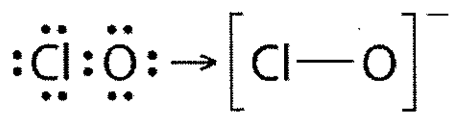


No electrons remain, but the sulfur atom can take 2 more pairs to satisfy the octet rule.

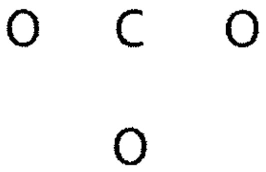


(b) ClO^-:
A chlorine atom has a bonding capacity of 1.

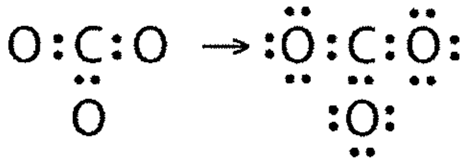
Cl atom: 7 e^-
O atom: 6 e^-
–1 charge of ClO^-: 1 e^-
Total: 14 e^-



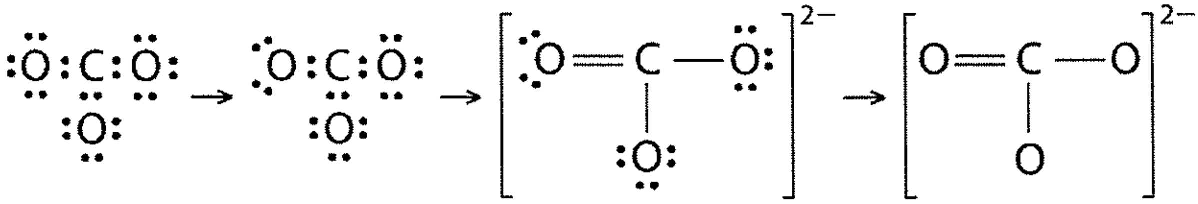
(c) CO_3^{2-}:
The carbon atom has the largest bonding capacity, 4.



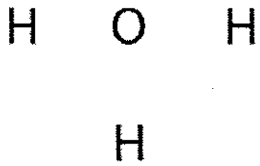
C atom: 4 e^-
3 O atoms: 3 (6 e^-) = 18 e^-
–2 charge of CO_3^{2-}: 2 e^-
Total: 24 e^-



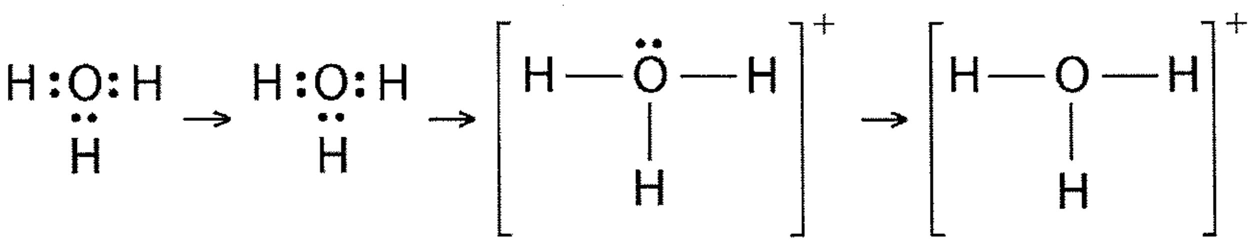
No electrons remain, but the carbon atom needs another pair to satisfy the octet rule.



(d) H_3O^+:



O atom: 6 e^-
3 H atoms: 3 (1 e^-) = 3 e^-
+1 charge of H_3O^+: –(1 e^-)
Total: 8 e^-



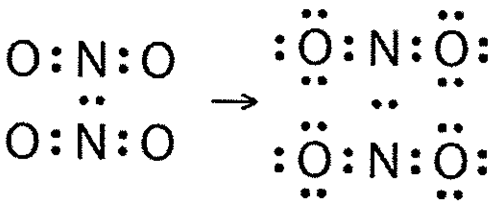
5. When ionic bonds form, there is a transfer of electrons, whereas when a covalent bond forms, electrons are shared. Ionic bonds occur mainly between a metal and a non-metal. Covalent bonds occur between two non-metals.

6. Answers may vary. Sample answer: To determine whether a substance is an ionic or molecular compound, you could determine its melting or boiling point (low for molecules and high for ionic compounds); test its conductivity when dissolved in water (good for ionic compounds and poor for molecular compounds); and test its hardness. An ionic compound will be hard; a molecular compound may be soft, waxy, and flexible.
7. Lewis structure for dinitrogen tetroxide, N_2O_4:
The nitrogen atoms have the largest bonding capacity, 3. Oxygen atoms can form 2 bonds.

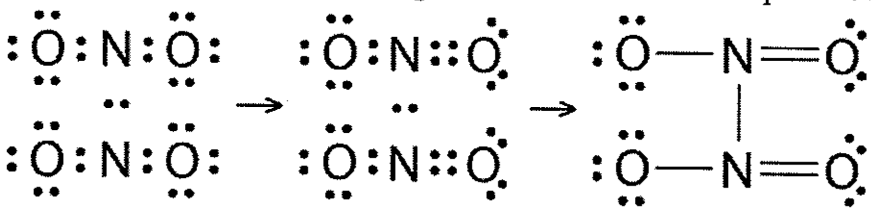
O N O

O N O

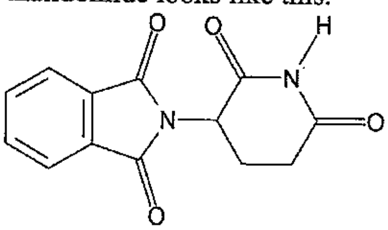
2 N atoms: 2 (5 e^-) = 10 e^-
4 O atoms: 4 (6 e^-) = 24 e^-
Total: 34 e^-



No electrons remain, but the nitrogen atoms each need another pair to satisfy the octet rule.



8. Answers may vary depending on research. Sample answer: Thalidomide is a sedative that was given to pregnant women in the late 1950s and early 1960s to reduce symptoms associated with morning sickness. However, it turned out that thalidomide causes severe birth defects or death of unborn babies. Canadians were not warned of this problem until months after the drug had been withdrawn in other countries after its effects became known. The molecular structure of thalidomide looks like this:



Section 2.3: Chemical Bonding and Electronegativity

Section 2.3 Questions, page 73

1. In the periodic table, electronegativity increases as one moves from left to right and from bottom to top. Atomic radius increases as one moves from right to left and from top to bottom.
2. In order of increasing electronegativity: Cs, K, Ca, Fe, Br, Cl, F.
3. In order to predict what type of bond will form in a compound, we need to find the electronegativity difference between the two elements involved. If the electronegativity difference is greater than 1.7, the bond will be ionic. If the electronegativity difference is between 0.5 and 1.7, the bond is polar covalent. If the electronegativity difference is below 0.5, the bond will be non-polar covalent.
4. A polar covalent bond is a covalent bond formed between atoms with significantly different electronegativities, thus resulting in a bond with localized positive and negative charges, or poles. A non-polar covalent bond is a covalent bond formed between atoms with identical (or very similar) electronegativities.
5. Electronegativity difference and type of bond formed between two elements:
(a) Ca–S: $\Delta EN = 1.6$, polar covalent
(b) H–F: $\Delta EN = 1.8$, ionic
(c) P–H: $\Delta EN = 0$, non-polar covalent
(d) C–Cl: $\Delta EN = 0.6$, polar covalent
(e) C–O: $\Delta EN = 0.8$, polar covalent
(f) Li–Cl: $\Delta EN = 2.2$, ionic
6. (a) H–F is a more polar bond than H–Cl.
(b) O–H is a more polar bond than C–H.
(c) C–N is a more polar bond than N–N.
7. (a) $N_2(g)$ has non-polar covalent bonds.
(b) $NH_3(g)$ has non-polar covalent bonds.
(c) $H_2O(l)$ has polar covalent bonds.
(d) FeO(s) has polar covalent bonds.
(e) $MgCl_2(s)$ has ionic bonds.
8. (a) The most ionic bond possible between any two elements in the periodic table is Fr–F, the bond that forms between an atom of francium, F, and an atom of fluorine, F. Fluorine has the highest electronegativity value of all the elements (4.0) and francium has the lowest (0.7), so the electronegativity difference between francium and fluorine (3.3) is the highest possible between two elements and thus Fr–F is the strongest ionic bond.
(b) A compound that contains the Fr–F bond would exhibit strong ionic compound characteristics: it would have a very high melting point and boiling point, it would be soluble in water, and it would form an electrolyte.
9. Answers may vary depending on research. Students should discuss Linus Pauling's work as a path-breaking chemist in the field of molecular structure and the nature of the chemical bond and as a social activist and educator.
10. Answers may vary depending on research. Students should explain Neil Bartlett's accomplishments and that Bartlett's work with inert gas compounds was one of the major Canadian discoveries in chemistry.

Section 2.4: Chemical Formulas and Nomenclature

Tutorial 1 Practice, page 75

1. Chemical formula for binary ionic compound:

(a) Magnesium oxide:

$$\begin{array}{cc} 2+ & 2- \\ \text{Mg} & \text{O} \end{array} \rightarrow \begin{array}{ccc} (+2) & + & (-2) = 0 \\ \text{Mg} & & \text{O} \end{array} \rightarrow \text{MgO}$$

The chemical formula for magnesium oxide is MgO.

(b) Aluminum fluoride:

$$\begin{array}{cc} 3+ & 1- \\ \text{Al} & \text{F} \end{array} \rightarrow \begin{array}{ccc} (+3) & + & 3(-1) = 0 \\ \text{Al} & & \text{F} \end{array} \rightarrow \text{Al}_1\text{F}_3$$

The chemical formula for aluminum fluoride is AlF_3.

(c) Potassium oxide:

$$\begin{array}{cc} 1+ & 2- \\ \text{K} & \text{O} \end{array} \rightarrow \begin{array}{ccc} 2(+1) & + & (-2) = 0 \\ \text{K} & & \text{O} \end{array} \rightarrow \text{K}_2\text{O}_1$$

The chemical formula for potassium oxide is K_2O.

2. Chemical formula for polyatomic ionic compound:

(a) Magnesium hydroxide:

$$\begin{array}{cc} 2+ & 1- \\ \text{Mg} & \text{OH} \end{array} \rightarrow \begin{array}{ccc} (+2) & + & 2(-1) = 0 \\ \text{Mg} & & \text{OH} \end{array} \rightarrow \text{Mg}_1(\text{OH})_2$$

The chemical formula for magnesium hydroxide is $Mg(OH)_2$.

(b) Sodium bicarbonate:

$$\begin{array}{cc} 1+ & 1- \\ \text{Na} & \text{HCO}_3 \end{array} \rightarrow \begin{array}{ccc} (+1) & + & (-1) = 0 \\ \text{Na} & & \text{HCO}_3 \end{array} \rightarrow \text{NaHCO}_3$$

The chemical formula for sodium bicarbonate is $NaHCO_3$.

(c) Aluminum phosphate:

$$\begin{array}{cc} 3+ & 3- \\ \text{Al} & \text{PO}_4 \end{array} \rightarrow \begin{array}{ccc} (+3) & + & (-3) = 0 \\ \text{Al} & & \text{PO}_4 \end{array} \rightarrow \text{AlPO}_4$$

The chemical formula for aluminum phosphate is $AlPO_4$.

Tutorial 2 Practice, pages 77 and 78

1. Chemical name for ionic compound:
(a) $CuSO_4$ contains copper, which is a multivalent metal.
SO_4 is the sulfate ion, with a charge of −2.
The total negative charge is −2, so the total positive charge is +2.
So, the charge on the Cu ion is +2.
The IUPAC name of $CuSO_4$ is copper(II) sulfate.
(b) CuCl contains copper, which is a multivalent metal.
The second element is Cl, so the second part of the compound's name is *chloride.*
The Cl ion has a charge of −1. The total negative charge is −1.
The charge on the Cu ion may be +1 or +2.
The total positive charge is +1, so the charge on the Cu ion is +1.
The IUPAC name of CuCl is copper(I) chloride.
(c) $SnCl_4$ contains tin, which is a multivalent metal.
The second element is Cl, so the second part of the compound's name is *chloride.*.
The Cl ion has a charge of −1. There are 4 Cl ions, each with a −1 charge. The total negative charge is −4.
The charge on the Sn ion may be +2 or +4.
The total positive charge is +4, so the charge on the Sn ion is +4.
The IUPAC name of $SnCl_4$ is tin(IV) chloride.
(d) SnO contains tin, which is a multivalent metal.
The second element is O, so the second part of the compound's name is *oxide.*
The O ion has a charge of −2. The total negative charge is −2.
The charge on the Sn ion may be +2 or +4.
The total positive charge is +2, so the charge on the Sn ion is +2.
The IUPAC name of SnO is tin(II) oxide.

2. Chemical name for ionic compound:
(a) $Pb(SO_3)_2$ contains lead, which is a multivalent metal.
SO_3 has one less O than the sulfate ion, SO_4^{2-}, so it is the sulfite ion, with a charge of −2.
The charge on the Pb ion may be +2 or +4.
There are 2 SO_3 ions, each with a −2 charge. The total negative charge is −4.
The total positive charge is +4, so the charge on the Pb ion is +4.
The IUPAC name of $Pb(SO_3)_2$ is lead(IV) sulfite.
(b) $Pb(NO_3)_2$ contains lead, which is a multivalent metal.
NO_3 is the nitrate ion, with a charge of −1.
The charge on the Pb ion may be +2 or +4.
There are 2 NO_3 ions, each with a −1 charge. The total negative charge is −2.
The total positive charge is +2, so the charge on the Pb ion is +2.
The IUPAC name of $Pb(NO_3)_2$ is lead(II) nitrate.
(c) Cu_3PO_4 contains copper, which is a multivalent metal.
PO_4 is the phosphate ion, with a charge of −3. The total negative charge is −3.
The charge on the Cu ion may be +1 or +2.
The total positive charge is +3, and there are 3 Cu ions, so the charge on the Cu ion is +1.
The IUPAC name of Cu_3PO_4 is copper(I) phosphate.

(d) $Fe(OH)_3$ contains iron, which is a multivalent metal.
OH is the hydroxide ion, with a charge of –1.
The charge on the Fe ion may be +2 or +3.
There are 3 OH ions, each with a –1 charge. The total negative charge is –3.
The total positive charge is +3, so the charge on the Fe ion is +3.
The IUPAC name of $Fe(OH)_3$ is iron(III) hydroxide.
(e) NaClO contains the sodium ion, Na, with a charge of +1.
ClO is an oxyanion with 2 fewer oxygen atoms than chlorate, so it is the hypochlorite ion, with a charge of –1.
The IUPAC name of NaClO is sodium hypochlorite.
(f) $(NH_4)_2CO_3$ contains the ammonium ion, NH_4, with a charge of +1, and the oxyanion CO_3, carbonate, with a charge of –2.
There are 2 ammonium ions, so the total positive charge is 2(+1) = +2.
The IUPAC name of $(NH_4)_2CO_3$ is ammonium carbonate.

Tutorial 3 Practice, page 79

1. (a) For a compound of calcium and chlorine, 1 Ca atom is needed for every Cl atom. The molecular compound is CaCl, or calcium chloride. There are 2 water molecules for each CaCl molecule, so this is a hydrate, and the prefix for "hydrate" is *di-*. The name of the hydrate is calcium chloride dihydrate, and the chemical formula is $CaCl\cdot 2H_2O$.
(b) The sodium ion, Na, has a charge of 1+ and the sulfate ion, SO_4, has a charge of 2–. Two Na ions are needed for each SO_4 ion to bring the total charge to zero. The chemical formula for sodium sulfate is Na_2SO_4.
There are 10 water molecules per formula unit of sodium sulfate, so this is a hydrate, and the prefix for "hydrate" is *deca-*. The name of the hydrate is sodium sulfate decahydrate, and the chemical formula is $Na_2SO_4\cdot 10H_2O$.

Tutorial 4 Practice, page 80

1. Name of molecular compound:
(a) CCl_4 is carbon tetrachloride.
(b) NO_2 is nitrogen dioxide.
(c) P_2O_5 is diphosphorous pentoxide.
(d) CF_4 is carbon tetrafluouride.
2. Chemical formula for molecular compound:
(a) Carbon monoxide is CO.
(b) Sulfur dioxide is SO_2.
(c) Phosphorus pentafluoride is PF_5.

Research This: What's in a Name?, page 80

Answers may vary. Sample answers:

A. Ingredients for dry cat food included brown rice, potassium chloride, ferrous sulfate, copper sulfate, manganous oxide, calcium iodate, and sodium selenite. These are all ionic compounds, except for brown rice.

B. The brown rice is a molecular compound.

C. Ionic compounds are composed of a metallic element combined with one or more non-metallic elements. Potassium, iron, copper, manganese, calcium, and sodium are all metals. Carbohydrates, such as rice, are made up of carbon, hydrogen, and oxygen, which are all non-metals, so carbohydrates are molecular compounds.

D. The chemical formulas of the compounds are: potassium chloride, KCL; ferrous sulfate, $FeSO_4$; copper sulfate, $CuSO_4$; manganous oxide, MnO; calcium iodate, $Ca(IO_3)_2$; and sodium selenite, Na_2SeO_3. Rice is a polysaccharide with the chemical formula $C_x(H_2O)_y$.

E. Not all of the compounds were named according to the IUPAC system. Ferrous sulfate is iron(II) sulfate or iron(III) sulfate, copper sulfate is copper(II) sulfate, manganous oxide is manganese(II) oxide, and calcium iodate is calcium diiodate.

Section 2.4 Questions, page 81

1. **(a)** Lithium chloride:

$$\overset{1+}{\text{Li}}\quad\overset{1-}{\text{Cl}} \rightarrow \underset{\text{Li}}{(+1)} + \underset{\text{Cl}}{(-1)} = 0 \rightarrow \text{LiCl}$$

The chemical formula for lithium chloride is LiCl.

(b) Potassium sulfide:

$$\overset{1+}{\text{K}}\quad\overset{2-}{\text{S}} \rightarrow \underset{\text{K}}{2(+1)} + \underset{\text{S}}{(-2)} = 0 \rightarrow \text{K}_2\text{S}_1$$

The chemical formula for potassium sulfide is K_2S.

(c) Iron(II) chloride:

$$\overset{2+}{\text{Fe}}\quad\overset{1-}{\text{Cl}} \rightarrow \underset{\text{Fe}}{(+2)} + \underset{\text{Cl}}{2(-1)} = 0 \rightarrow \text{Fe}_1\text{Cl}_2$$

The chemical formula for iron(II) chloride is $FeCl_2$.

(d) Aluminum oxide:

$$\overset{3+}{\text{Al}}\quad\overset{2-}{\text{O}} \rightarrow \underset{\text{Al}}{2(+3)} + \underset{\text{O}}{3(-2)} = 0 \rightarrow \text{Al}_2\text{O}_3$$

The chemical formula for aluminum oxide is Al_2O_3.

(e) Sodium sulfate:

$$\overset{1+}{\text{Na}}\quad\overset{2-}{\text{SO}_4} \rightarrow \underset{\text{Na}}{2(+1)} + \underset{\text{SO}_4}{(-2)} = 0 \rightarrow \text{Na}_2(\text{SO}_4)_1$$

The chemical formula for sodium sulfate is Na_2SO_4.

(f) Tin(IV) oxide:

$$\overset{4+}{\text{Sn}}\ \overset{2-}{\text{O}} \rightarrow \overset{(+4)}{\text{Sn}} + \overset{2(-2)}{\text{O}} = 0 \rightarrow Sn_1O_2$$

The chemical formula for tin(IV) oxide is SnO_2.

2. For an ionic compound with a multivalent metal, IUPAC naming rules involve indicating which specific ion it is by using a Roman numeral after the name of the ion; for example, FeO is iron(II) oxide.

3. (a) The IUPAC name for $MgCl_2$ is magnesium chloride.

(b) The IUPAC name for Cs_2O is cesium oxide.

(c) The IUPAC name for FeS is iron(II) sulfide.

(d) Na is sodium and PO_4 is the phosphate ion.
The IUPAC name for Na_3PO_4 is sodium phosphate.

(e) NH_4 is the ammonium ion and NO_3 is the nitrate ion.
The IUPAC name for NH_4NO_3 is ammonium nitrate.

(f) Al is aluminum and SO_4 is the nitrate ion.
The IUPAC name for $Al_2(SO_4)_3$ is aluminum sulfate.

(g) Mg is magnesium and ClO_3 is the chlorate ion.
The IUPAC name for $Mg(ClO_3)_2$ is magnesium chlorate.

(h) The IUPAC name for $Pb(BrO_3)_2$ is lead(II) bromate.

(i) The IUPAC name for $ZnHPO_4$ is zinc hydrogen phosphate.

(j) The IUPAC name for NaCN is sodium cyanide.

4. (a) The IUPAC name for PCl_5 is phosphorous pentachloride.

(b) The IUPAC name for N_2O_5 is dinitrogen pentoxide.

(c) The IUPAC name for CF_4 is carbon tetrafluoride.

(d) The IUPAC name for SO_2 is sulfur dioxide.

5. Chemical formula for anhydrous cobalt(II) chloride:

$$\overset{2+}{\text{Co}}\ \overset{1-}{\text{Cl}} \rightarrow \overset{(+2)}{\text{Co}} + \overset{2(-1)}{\text{Cl}} = 0 \rightarrow Co_1Cl_2$$

The chemical formula for anhydrous cobalt(II) chloride is $CoCl_2$.
The hydrated form, cobalt(II) chloride hexahydrate, has 6 water molecules for each formula unit of CoCl, so the chemical formula for the hydrated form is $CoCl_2 \cdot 6H_2O$.

6. (a) The chemical formula for phosphorus trichloride is PCl_3.

(b) The chemical formula for carbon tetrachloride is CCl_4.

(c) The chemical formula for nitrogen monoxide is NO.

(d) The chemical formula for disulfur dichloride is S_2Cl_2.

7. (a) The chemical name for KOH is potassium hydroxide.

(b) The chemical name for $NaNO_2$ is sodium nitrite.

(c) The chemical name for CuCl is copper(I) chloride.

(d) The chemical name for NaOH is sodium hydroxide.

(e) The chemical name for $CaCO_3$ is calcium carbonate.

8. It is important to have a standardized IUPAC nomenclature system so that scientists and professionals can communicate the name and chemical formula for any chemical in the same way. This system avoids confusion that could lead to mistakes in use of chemicals.

Chapter 2 Self-Quiz, page 87

1. (b)
2. (c)
3. (d)
4. (a)
5. (a)
6. (c)
7. (b)
8. (b)
9. (c)
10. False. The *formula unit* for the compound sodium chloride is NaCl(s). Or The *chemical* formula for the compound sodium chloride is NaCl(s).
11. False. The chemical bond that forms between a hydrogen atom and a chlorine atom will be *polar* covalent.
12. True
13. False. A molecule of carbon dioxide would have carbon–oxygen *double* bonds in its Lewis structure.
14. False. In the periodic table, electronegativity values increase from *bottom* to *top* and from left to right.
15. True
16. True
17. False. The chemical formula for the meat preservative sodium nitrite is $NaNO_2$.
18. False. The chemical formula for the compound tin(IV) sulfide is SnS_2.
19. False. The charge on the chromate ion in the compound potassium chromate, K_2CrO_4(s), is *–2*.
20. True