PRACTICE

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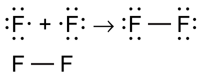
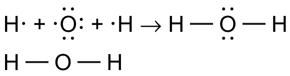
Understanding Concepts

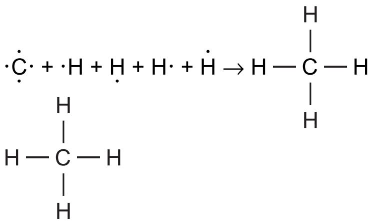
1. (a) $F_{2(g)}$



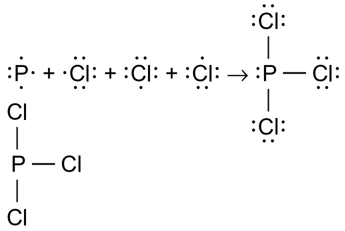
(b) $H_2O_{(l)}$



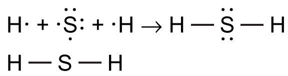
(c) $CH_{4(g)}$



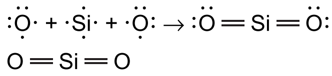
(d) $PCl_{3(s)}$



(e) $H_2S_{(g)}$



(f) $SiO_{2(s)}$



PRACTICE

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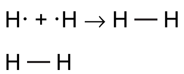
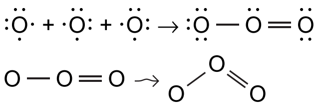
Understanding Concepts

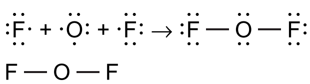
2. (a) $H_{2(g)}$



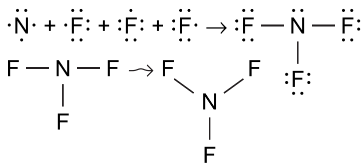
(b) $O_{3(g)}$



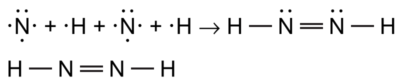
(c) $OF_{2(g)}$



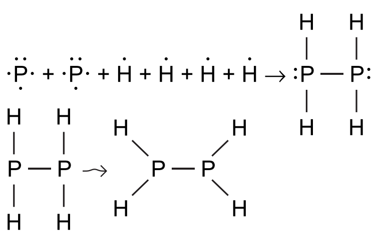
(d) $NF_{3(g)}$



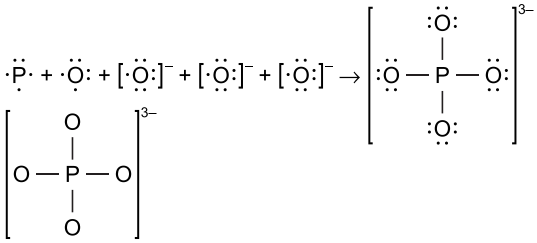
(e) $N_2H_{2(g)}$



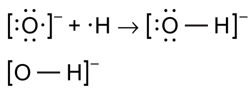
(f) $P_2H_{4(g)}$



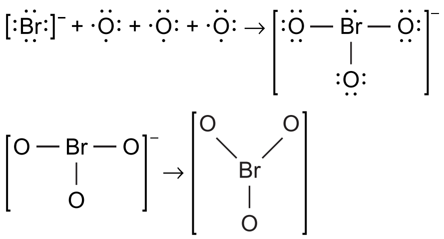
3. (a) $PO_{4(aq)}^{3-}$



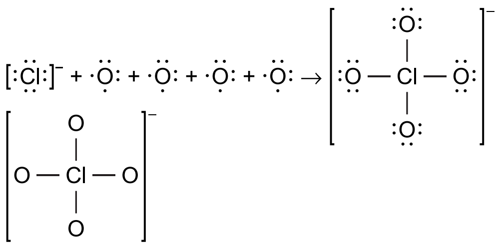
(b) $OH_{(aq)}^{-}$



(c) $BrO_{3(aq)}^{-}$



(d) $ClO_{4(aq)}^{-}$



4. Ozone, question 2(b), can be considered to have a coordinate covalent bond, with one of the oxygens starting as $[O]^{2-}$. Question 3 (a), (c), and (d) have coordinate covalent bonds; (b) would have a coordinate covalent bond if the ions involved are $[O]^{2-}$ and $[H]^{+}$.

PRACTICE

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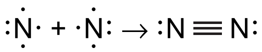
Understanding Concepts

5. The term "bonding electrons" describes a pair of electrons that are shared by two atoms forming a covalent bond, whereas the term "lone pairs" describes a pair of electrons not involved in bonding.
6. (a) covalent
   (b) covalent
   (c) ionic
   (d) ionic
7. (a) Molecular elements and compounds: $N_{2(g)}$, $O_{2(g)}$, $F_{2(g)}$, $C_{12}H_{22}O_{11(s)}$ (sugar), $C_6H_{6(l)}$ (liquid benzene), $NH_{3(g)}$ (ammonia).
   Ionic compounds: $NaCl_{(s)}$, $MgO_{(s)}$, $Ca(OH)_{2(s)}$, $CaF_{2(s)}$, $NaHCO_{3(s)}$, $CaCO_{3(s).}$
   (b) Molecular elements and compounds are formed by covalent bonds. Molecular compounds may be solids, liquids, or gases at SATP and tend to be soft or waxy. Covalent bonds between the atoms are strong. However, the intermolecular forces in molecular compounds are weaker in comparison — adding a relatively small amount of heat will cause a solid molecular compound to change state from a solid to a liquid, and then to a gas. Ionic compounds are formed by ionic bonds. Ionic compounds are solids at SATP and are hard and brittle. The properties of ionic compounds are due to the strong, simultaneous forces of attraction between the positive and negative ions, which hold the ions firmly in a rigid structure.
8. (a) The bonding capacity of nitrogen is three, and the bonding capacity of chlorine is one.

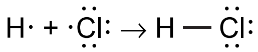
(b) The number of covalent bonds (shared electron pairs) that an atom can form is known as its bonding capacity. Each atom of nitrogen shares three electron pairs, so it has a bonding capacity of three. Each atom of chlorine shares one electron pair, so it has a bonding capacity of one.

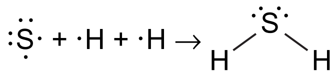
9. Coordinate covalent bonds are similar to covalent bonds in that once the bond is formed, there is no way to tell the difference from a covalent bond. Coordinate covalent bonds are different from covalent bonds in that instead of having the shared electrons come from both atoms, both of the shared electrons come from the same atom.

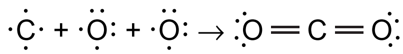
10. (a) Two nitrogen atoms require three electrons each to form stable octets. The two atoms form a triple bond by sharing three electron pairs.

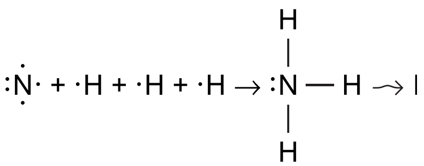
(b) 

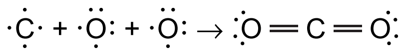
(c) The strength of a bond between two atoms increases as the number of electron pairs in the bond increases. The triple bond in a nitrogen molecule is very strong, preventing the atoms from forming a bond with another atom.

11. (a) HCl 

(c) H_2S 



(b) NH_3 

(d) CO_2 

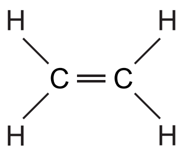
12. Bonding Capacities of Some Common Atoms

Atom	Number of valence electrons	Number of bonding electrons	Bonding capacity
carbon	4	4	4
nitrogen	5	3	3
oxygen	6	2	2
hydrogen	1	1	1
fluorine	7	1	1
chlorine	7	1	1
bromine	7	1	1
odine	7	1	1

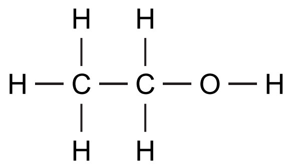
13. (a) O_2 O — O

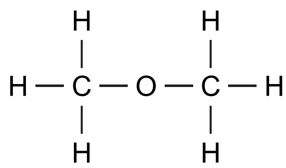
(b) Br_2 Br — Br

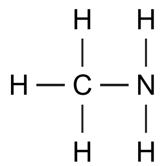
(c) H_2O_2 H — O — O — H

(d) C_2H_4 

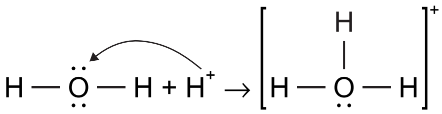
(e) HCN H — C ≡ N

(f) C_2H_5OH 

(g) CH_3OCH_3 

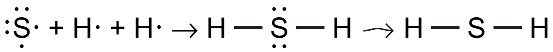
(h) CH_3NH_2 

14. (a)



   (b) There are covalent and coordinate covalent bonds within the hydronium ion.
   (c) Ionic bonds. (Note that it will also form hydrogen bonds.)

15. It is incorrect to show the structural formula of H_2S as H—H—S. The central H atom is shown as bonding to two other atoms — yet the bonding capacity of hydrogen is one. The correct structural formula is H–S–H and its formation is shown below:



SECTION 2.3 QUESTIONS

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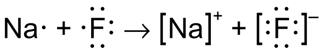
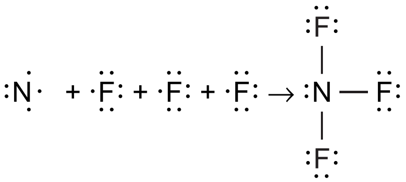
Understanding Concepts

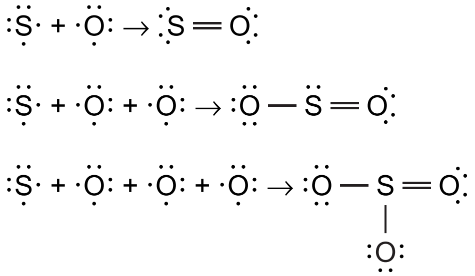
1. (a) Properties of compound A: a solid at SATP, is hard and brittle, has a high melting point, and its solution conducts electricity.
   Properties of compound B: may be a solid, a liquid, or a gas at SATP — if a solid it is soft, waxy or flexible, has a low melting point, and its solution does not conduct electricity.
   (b) Compound A is an ionic compound involving the bonding of a metal with a nonmetal. Sodium, a metal, has formed an ionic bond with fluorine, a nonmetal.
   Compound B is a molecular compound involving the bonding of a nonmetal with another nonmetal. Nitrogen, a nonmetal, has formed covalent bonds with fluorine, also a nonmetal.
   (c)





2. The difference in electronegativities between aluminum and oxygen is strong enough to transfer electrons from the metal atom to the nonmetal atom, producing ionic bonds and an ionic compound. Metals and nonmetals show a periodic trend to form ionic compounds, and the metals of Group 13 show a periodic trend to form ionic oxides (compounds composed of a metal and oxygen) when burned in air.
   The difference in electronegativities between carbon and oxygen is not strong enough to transfer electrons, and instead, the electrons are shared in a covalent bond, resulting in the formation of a molecular compound. Nonmetals show a periodic trend to combine with other nonmetals to form molecular compounds.
3. (a) Group 1 metals readily react with the nonmetal elements in Group 17 to form ionic compounds, with the general formula MX.
   (b) The compound MX is a solid at SATP, is hard and brittle, has a high melting point, and its aqueous solution conducts electricity.
4. (a) NaCl is an ionic compound; Cl_2 is a covalent compound.
   (b) NaCl is a solid at SATP because of the strong ionic bonds. The simultaneous forces of attraction between the positive and negative ions hold the ions firmly in a rigid structure.
   Cl_2 is a gas at SATP because of the weak intermolecular forces between the Cl_2 molecules. The covalent bonds between the Cl atoms are strong, but with the addition of a relatively small amount of heat, the intermolecular forces between Cl_2 molecules are easily overcome, causing the molecular compound to be a gas at SATP.

5. Some of the molecular compounds that can be created using oxygen and sulfur include SO, SO_2 , SO_3.



From the examples above, SO contains only multiple bonds.

Applying Inquiry Skills

6. **Experimental Design**
Solubility: Obtain a small amount of compound A. Observe and record its state at the ambient temperature. Add a small quantity of the substance to about 10 mL of distilled water. Stir the mixture with a stirring rod and note whether the chemical dissolves. Many ionic compounds readily dissolve in water.
Conductivity: Obtain a small sample of distilled water in a beaker. Use a low-voltage conductivity apparatus to test the electrical conductivity of the sample. The apparatus should indicate a reading of zero. Test the electrical conductivity of the mixture from the above solubility procedure and record observations. Ionic compounds (many of which dissolve readily in water) form solutions that conduct electricity.
Repeat the procedure for compound B. Molecular compounds (some of which dissolve in water) form solutions that do not conduct electricity.

7. **Experimental Design**
State, Hardness and Brittleness: Obtain a small-sized piece of $NaCl_{(s)}$ in road salt form. Observe and, in a table, record its state at SATP, its hardness, and brittleness.
Solubility: Pour about 10 mL of distilled water into a 50-mL beaker. Add a small quantity of the road salt to the water. Use a stirring rod to stir the mixture. Note whether the road salt dissolves.
Conductivity: Obtain a small sample of distilled water in a beaker. Test the electrical conductivity of the sample. The apparatus should indicate a reading of zero. Test the conductivity of the mixture of sodium chloride and water from the Solubility procedure. Record observations.

2.4 ELECTRONEGATIVITY, POLAR BONDS, AND POLAR MOLECULES

PRACTICE

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Understanding Concepts

1. To predict whether a chemical bond between two atoms will be ionic, polar covalent, or covalent, we must consider the electronegativities of the elements involved. The absolute value of the difference in electronegativities of two bonded atoms provides a measure of the polarity in the bond: the greater the difference, the more polar the bond. By convention, a difference in electronegativity greater than 1.7 indicates an ionic bond.
2. (a) covalent
(b) covalent
(c) ionic
(d) ionic
(e) covalent
(f) covalent
(g) covalent
(h) ionic
(i) covalent
Si and O would be the most polar of the covalent bonds.
3. (a) H—F
(b) C—O
(c) O—H
(d) P—Cl
(e) N—H
(f) P—O
(g) C—N

