Answers to Review #2: Bonding, Structure and Properties of Substances (Chapter 4)

1. Know the meanings of, and be able to apply, the following terms:

allotropes	expanded valence	London dispersion forces	polar covalent bond
coordinate covalent bond	hydrogen bonding	metallic bonding	polar molecule
crystal lattice	inter-molecular attraction	network solid	resonance structures
dipole-dipole forces	intra-molecular attraction	octet rule	VSEPR Theory

2. Compare the four types of bonding that were discussed in this course by completing the chart:

Type of Bond	**Types of Atoms involved**	**ΔEN**	**Ionization Energies Of Bonding Atoms**	**Describe How the Electrons are Arranged in the Bond**	**Describe the Polarity of the Bond**
pure covalent	two non-metal atoms	<0.50	both atoms have high IE	the bonding electrons are shared approximately equally between bonded atoms	bond is essentially non-polar
polar covalent	two non-metal atoms	0.50 – 1.70	both atoms have high IE	the bonding electrons are significantly shifted toward the atom with higher EN	bond is significantly polar, creating δ+ and δ- charges
ionic	a non-metal and a metal atom	>1.70	one atom has high IE, one has low IE	the bonding electrons are essentially transferred to the atom with higher EN	bond is strongly polar with full + and – charges
metallic	metal atom only	<0.50ish (small)	both atoms have low IE	the valence electrons are delocalized; they are found in a random "electron sea" around the positive metal ions	bond is essentially non-polar

3. Describe how you could distinguish between the following substances using their properties:

a) a metal and an ionic substance
- can be distinguished because metallic substances conduct electricity in their pure, usually solid, form while ionic substances conduct electricity only in their aqueous or molten form, not as solids

b) a pure covalent compound and a polar covalent compound
- can be distinguished because a pure covalent compound is non-polar so it will not dissolve in a polar solvent such as water
- polar covalent compounds are polar so they dissolve well in polar solvents such as water

c) a pure covalent compound and a network solid
- can be distinguished based on melting point. Pure covalent compounds have relatively low melting points while network solids have very high melting points
- these substances can not be distinguished based on solubility in water because neither will dissolve in polar solvents such as water (however, pure covalent substances will dissolve in non-polar solvents such as benzene, while network solids are insoluble)

d) polar covalent compound and an ionic compound
- both of these types of compounds are generally soluble in water
- they can be distinguished by their ability to conduct an electric current in aqueous solution
- all ionic compounds are electrolytes because they dissociate in water to produce ions that can conduct
- most polar covalent compounds are not electrolytes so they do not produce ions when they are dissolved in water (the exception is acids, which are polar covalent but also electrolytes)

4. Explain the following:

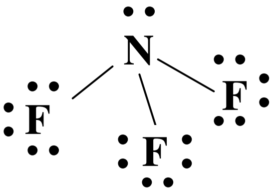
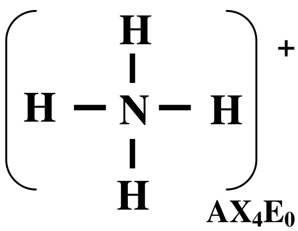
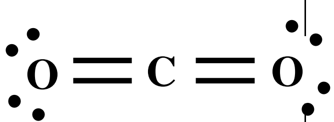
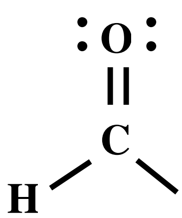
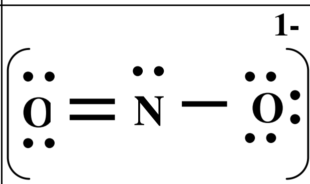
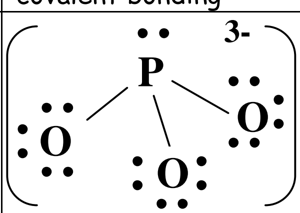
a) How a compound may contain polar bonds, but not be a polar molecule.
   - the polarity of a molecule depends on BOTH the polarity of the bonds in the molecule and the symmetry of the molecule
   - if a compound contains polar bonds ($\Delta EN > 0.50$), but the molecule is symmetrical in all planes, then the bond polarity will cancel out and the molecule will be non-polar overall

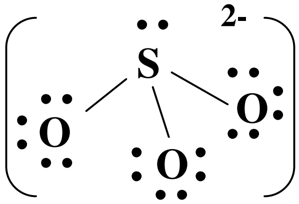
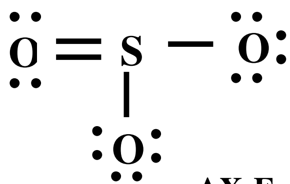
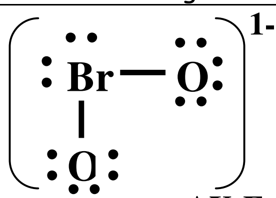
b) How the physical properties of a substance are related to the nature of the inter-molecular attractions.
   - as the polarity of the molecules (particles) of a substance increases, there are more significantly charged regions on the molecule and these will cause inter-molecular attraction between molecules
   - as the strength of inter-molecular attraction increases, the particles are held more tightly together, so they have higher melting and boiling points, are harder solids and have weaker odours, for example:
     i) non-polar molecules are essentially uncharged overall, so there are only London dispersion forces (LDFs) between molecules. Because LDFs are very weak, these substances are often gases or liquids at room temperature, they have very low melting and boiling points and often have odours
     ii) polar molecules have partially charged regions, so there are both LDFs and dipole-dipole attractions between molecules. Molecules are significantly attraction to each other, so these substances are often liquids or soft solids at room temperature, they have medium melting and boiling points and often have odours (as polarity increases, melting and boiling points increase)
     iii) ionic substances have fully charged regions so there are strong ionic (electrostatic) attractions between molecules. Ions are strongly attracted to one another, so these substance are solids at room temperature, have very high melting and boiling points and usually do not have odours

c) Why metals are good conductors of electricity.
   - metals are held together by metallic bonding. Metal atoms pool their valence electrons into a delocalized "electron sea" which surrounds the metal cations. Valence electrons can move easily between metal cations
   - metals are good conductors of electricity because of the delocalized "electron sea". When a current of electricity (a stream of electrons) is applied to a metal, the electrons can move easily from one metal cation to another and be conducted through the metal

d) Why network solids have such high melting points.
   - network solids such as diamond, graphite and silicon dioxide (sand) are held together by covalent bonds in two or three dimensions
   - because of the number and strength of covalent bonds, it takes a great deal of energy to separate the atoms from one another, so network solids have very high melting points

5. Use "the System" to draw the following molecules that obey the octet rule:

Compound	Draw the Lewis Structure	General Formula (AX_nE_m)	Name of the Shape of Molecule	Molecule Polar or Non-Polar?	Type(s) of Inter-Molecular Attraction	Properties (state at SATP, melting point, solubility, electrolyte?)
NF_3 have 26 e- need 32 e- 6e- in bonds = 3 bonds 20e- in LP		AX_3E_1	Trigonal pyramidal	Polar (it is asymmetrical)	• LDFs • dipole-dipole	• probably liquid at SATP • medium melting point • soluble in water • non-electrolyte
NH_4^+ have 8 e- need 16 e- 8e- in bonds = 4 bonds no e- in LP	 ‡ has coordinate covalent bonding	AX_4E_0	Tetrahedral	The NH_4+ ion is non-polar (it is symmetrical)	• LDFs • hydrogen bonding • ionic attraction	• solid at SATP • high melting point • soluble in water • electrolyte
CO_2 have 16 e- need 24 e- 8e- in bonds = 4 bonds 8 e- in LP		AX_2E_0	Linear	Non-polar (it is symmetrical)	• LDFs only	• gas at SATP • low melting point • only slightly soluble in water • non-electrolyte
CH_2O have 12 e- need 20 e- 8e- in bonds = 4 bonds 8 e- in LP		AX_3E_0	Trigonal planar	Polar (it is asymmetrical)	• LDFs • dipole-dipole	• probably liquid at SATP • medium melting point • soluble in water • non-electrolyte
NO_2^{-1} have 18 e- need 24 e- 6e- in bonds = 3 bonds 12 e- in LP	 * forms resonance structures ‡ has coordinate covalent bonding	AX_2E_1	Bent (angular or V-shaped)	Polar (it is asymmetrical)	• LDFs • dipole-dipole • ionic attraction	• probably solid at SATP • high melting point • soluble in water • electrolyte
PO_3^{3-} have 26 e- need 32 e- 6e- in bonds = 3 bonds 20 e- in LP	 ‡ has coordinate covalent bonding	AX_3E_1	Trigonal pyramidal	Polar (it is asymmetrical)	• LDFs • dipole-dipole • ionic attraction	• probably solid at SATP • high melting point • soluble in water • electrolyte

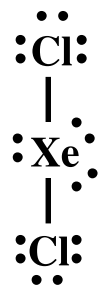
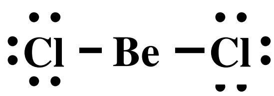
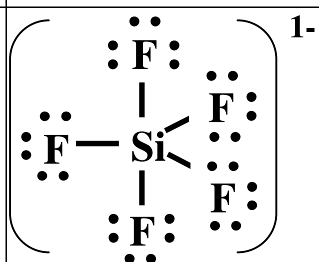
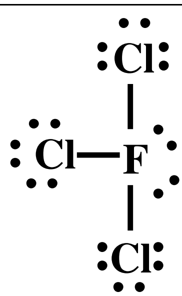
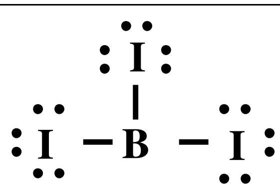
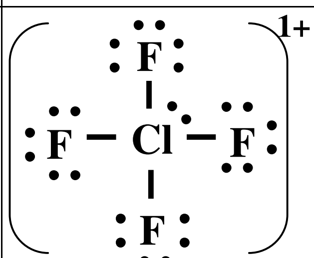
SO_3^{2-} have 26 e- need 32 e- 6e- in bonds = 3 bonds 20 e- in LP	 AX_3E_1 ‡ has coordinate covalent bonding	Trigonal pyramidal	Polar (it is asymmetrical)	• LDFs • dipole-dipole • ionic attraction	• probably solid at SATP • high melting point • soluble in water • electrolyte
SO_3 have 24 e- need 32 e- 8e- in bonds = 4 bonds 16 e- in LP	 AX_3E_0 * forms resonance structures ‡ has coordinate covalent bonding	Trigonal planar	Non-polar (it is symmetrical because of resonance)	• LDFs	• gas at SATP • low melting point • insoluble in water • non-electrolyte
BrO_2^- have 20 e- need 24 e- 4e- in bonds = 2 bonds 16 e- in LP	 AX_2E_2 ‡ has coordinate covalent bonding	Bent (angular or V-shaped)	Polar (it is asymmetrical)	• LDFs • dipole-dipole • ion to ion	• solid at SATP • high melting point • soluble in water • electrolyte

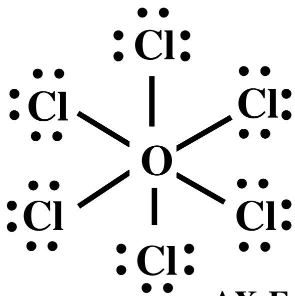
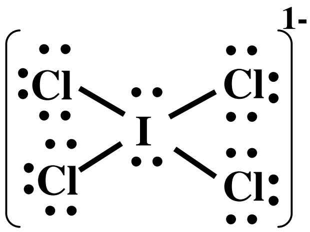
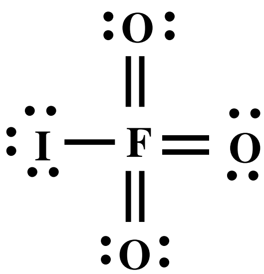
6. Referring to the molecules in question 5:

a) Put a * beside the structures which are resonance structures.

b) Put a ‡ beside the structures that show coordinate covalent bonding.

7. Draw the following molecules that do **NOT** obey the octet rule:

Compound	Draw the Lewis Structure	General Formula (AX_nE_m)	Name of the Shape of Molecule	Molecule Polar or Non-Polar?	Type(s) of Inter-Molecular Attraction	Properties (state at SATP, melting point, solubility, electrolyte?)
$XeCl_2$ have 22 e- 2 bonds so 4 e- in bonds 18 e- in LP		AX_2E_3	linear	Non-polar (it is symmetrical)	• LDFs	• probably gas at SATP • low melting point • insoluble in water • non-electrolyte
$BeCl_2$ have 16 e- 2 bonds so 4 e- in bonds 12 e- in LP		AX_2E_0	linear	Non-polar (it is symmetrical)	• LDFs	• probably gas at SATP • low melting point • insoluble in water • non-electrolyte
SiF_5^- have 40 e- 5 bonds so 10 e- in bonds 30 e- in LP		AX_5E_0	Trigonal Bipyramidal	The SiF_5^- ion is non-polar (it is symmetrical)	• LDFs • ionic attraction	• solid at SATP • high melting point • soluble in water • electrolyte
FCl_3 have 28 e- 3 bonds so 6 e- in bonds 22 e- in LP		AX_3E_2	T-shaped	FCl_3 is polar (it is asymmetrical)	• LDFs • dipole-dipole	• probably liquid at SATP • medium melting point • soluble in water • non-electrolyte
BI_3 have 24 e- 3 bonds so 6 e- in bonds 18 e- in LP		AX_3E_0	Trigonal planar	Non-polar (it is symmetrical)	• LDFs	• probably gas at SATP • low melting point • insoluble in water • non-electrolyte
ClF_4^+ have 34 e- 4 bonds so 8 e- in bonds 26 e- in LP		AX_4E_1	See-saw	ClF_4^+ is polar (it is asymmetrical)	• LDFs • dipole-dipole • ion to ion	• probably solid at SATP • high melting point • soluble in water • electrolyte

Compound	Draw the Lewis Structure	General Formula (AX_nE_m)	Name of the Shape of Molecule	Molecule Polar or Non-Polar?	Type(s) of Inter-Molecular Attraction	Properties (state at SATP, melting point, solubility, electrolyte?)
OCl_6 have 48 e- 6 bonds so 12 e- in bonds 36 e- in LP		AX_6E_0	octahedral	Non-polar (it is symmetrical)	• LDFs	• probably gas at SATP • low melting point • insoluble in water • non-electrolyte
ICl_4^- have 36 e- 4 bonds so 8 e- in bonds 28 e- in LP		AX_4E_2	square planar	Non-polar (it is symmetrical)	• LDFs • ion to ion	• solid at SATP • high melting point • soluble in water • electrolyte
FIO_3 have 32 e- 7 bonds so 14 e- in bonds 18 e- in LP		AX_4E_0	Tetrahedral	Polar (it is asymmetrical)	• LDFs • dipole-dipole	• probably liquid at SATP • medium melting point • soluble in water • non-electrolyte