1. Rank the following in increasing bond polarity: CC, BO, NH, LiF
   a. CC < NH < BO < LiF
   b. BO < CC < LiF < NH
   c. NH < BO < LiF < CC
   d. CC < BO < NH < LiF

Homonuclear diatomic molecules are never polar.

BO: 3.5 -2 = 1.5
NH: 3 - 2.2 = .8
LiF: 4-1 = 3

2. Which of the following can be polar molecules:
   I. CO₂
   II. Fe(CO)₅
   III. O₃
   a. I
   b. I, II, III
   c. III
   d. I, II

Carbon has double bonds with both oxygens and is therefore linear. The polarity of the bonds in CO₂ cancel out. Fe(CO)₅ has a trigonal bipyramidal geometry. The molecule is symmetric and there is no net dipole. The central oxygen in O₃ will have a positive dipole and the other two oxygens will have negative dipoles. Ozone has a bent molecular geometry and these dipoles do not cancel, making the molecule polar.

3. Which of the following molecules is nonpolar?
   a. NH₃
   b. SO₄ ²-
   c. SO₂
   d. BF₂Cl

SO₄ ²- has two double bonds to two oxygens and single bonds with the other oxygens. The single oxygens carry the negative charges. Each of these bonds are polar but the molecule has a tetrahedral geometry and the dipoles cancel.

4. Determine the molecular geometry and bond angles of bromine pentafluoride (BrF₅)
   a. Octahedral, 90, 120
   b. Square Pyramidal, 90
   c. Octahedral, 90
   d. Square Pyramidal, 90, 120

VSPER says that BrF₅ has an octahedral electronic geometry and a square pyramidal molecular geometry since Br has one lone pair.

5. Which hybrid orbitals are present in XeF₄?
   a. dsp³
   b. d²sp³
   c. d²sp²
   d. sp³

Xe has four covalent bonds with F and two lone pairs. There are 6 regions of electrons around Xe so it will hybridize two d atomic orbitals, 1 s orbital, and 3 p orbitals to make 6 hybrid d²sp³ orbitals.

6. Determine the electronic geometry of ICl₂⁻.
   a. Trigonal pyramidal
   b. Bent
   c. Tetrahedral
7. Determine the molecular geometry of the oxygen in CH3OH.
   a. Tetrahedral
   b. Bent
   c. Linear
   d. Seesaw

   Oxygen has two covalent bonds and two lone pairs. It has a tetrahedral electronic geometry and a bent molecular geometry.

8. How many σ and π bonds are there in $\text{C}_2\text{H}_2$?
   a. $4\sigma$ and $1\pi$
   b. $3\sigma$ and $2\pi$
   c. $2\sigma$ and $3\pi$
   d. $3\sigma$ and $1\pi$

   $\text{C}_2\text{H}_2$ has two single bonds and one triple bond. Every single bond is a sigma bond since the atomic or hybrid orbitals can directly overlap on the internuclear axis. Double bonds and triple bonds always have one sigma bond and one or two pi bonds respectively. The carbons are sp hybridized and these four hybrid orbitals are used in sigma bonding. The remaining four p orbitals are used in triple bonding.

9. What atomic orbitals are used in the bonding of NO?
   a. 2s
   b. 2s and 2p
   c. 2p
   d. 1s, 2s, 2p

   The 1s and 2s orbitals do not contribute to bonding. The two n2p orbitals and the σ2p orbital are filled with electrons from the 2p electrons from nitrogen and oxygen. One electron remains and occupies a n2p* antibonding orbital.

10. Using molecular orbital theory determine which of the following molecules can exist and no be paramagnetic.
    a. $\text{B}_2$
    b. $\text{He}_2$
    c. CO
    d. NO

    He2 cannot exist because it has a bond order of 0. CO has no unpaired electrons in its molecular orbitals. B2 has two unpaired electrons in the n2p orbitals. NO has one unpaired electron in its n2p* molecular orbital.

Miranda, Question Types 11-20.
11. What is the electronic configuration of $\text{B}_2^-$?
    a. $(\sigma2s)^2(\sigma2s^*)^2(\pi2p)^4$
    b. $(\sigma2s)^2(\sigma2s^*)^2$
    c. $(\sigma2s)^2(\sigma2s^*)^2(\pi2p)^2$
    d. $(\sigma2s)^2(\sigma2s^*)^2(\sigma2p)^2(\pi2p)^2$

    The filled MO for $\text{B}_2^-$:
    $\sigma2p^*$
    $\pi2p^*, \pi2p^*$
    $\sigma2p$
    $\pi2p, \pi2p$
    $\sigma2s^*$
12. What are the bond orders for $\text{N}_2^+$, $\text{N}_2$, and $\text{N}_2^-$?
   a. 3.5; 3; 3.5
   b. 2; 3; 4
   c. 2.5; 3; 3.5
   d. 2.5; 3; 2.5
   
The filled MO for $\text{N}_2$:
   $\sigma_{2p^*}$
   $\pi_{2p^*, \pi_{2p^*}}$
   $\sigma_{2p}$
   $\pi_{2p, \pi_{2p}}$
   $\sigma_{2s^*}$
   $\sigma_{2s}$
   $\sigma_{1s^*}$
   $\sigma_{1s}$
   BO for $\text{N}_2^+$ = $(9 - 4) / 2 = 2.5$
   BO for $\text{N}_2$ = $(10 - 4) / 2 = 3$
   BO for $\text{N}_2^-$ = $(10 - 5) / 2 = 2.5$

13. Which molecule is diamagnetic?
   a. $\text{B}_2^{2-}$
   b. $\text{C}_2^{2+}$
   c. $\text{O}_2$
   d. all are diamagnetic
   
The filled MO for $\text{B}_2^{2-}$:
   $\sigma_{2p^*}$
   $\pi_{2p^*, \pi_{2p^*}}$
   $\sigma_{2p}$
   $\pi_{2p, \pi_{2p}}$
   $\sigma_{2s^*}$
   $\sigma_{2s}$
   $\sigma_{1s^*}$
   $\sigma_{1s}$

   The filled MO for $\text{C}_2^{2+}$:
   $\sigma_{2p^*}$
   $\pi_{2p^*, \pi_{2p^*}}$
   $\sigma_{2p}$
   $\pi_{2p, \pi_{2p}}$
   $\sigma_{2s^*}$
   $\sigma_{2s}$
   $\sigma_{1s^*}$
   $\sigma_{1s}$

   The filled MO for $\text{O}_2$:
   $\sigma_{2p^*}$
   $\pi_{2p^*, \pi_{2p^*}}$
   $\pi_{2p, \pi_{2p}}$
   $\sigma_{2p}$
   $\sigma_{2s^*}$
   $\sigma_{2s}$
   $\sigma_{1s^*}$
   $\sigma_{1s}$
14. Based on bond order, what is true about the difference between the bonds in Li\(_2\) and C\(_2\)?
   a. C\(_2\) has a longer bond length and a higher bond energy than Li\(_2\).
   b. C\(_2\) has a longer bond length and a lower bond energy than Li\(_2\).
   c. C\(_2\) has a shorter bond length and a higher bond energy than Li\(_2\).
   d. C\(_2\) has a shorter bond length and a lower bond energy than Li\(_2\).

   The bond order for C\(_2\) is 2, and the bond order for Li\(_2\) is 1. Bond length is inversely proportional to bond order, so C\(_2\) has a shorter bond length than Li\(_2\). Bond energy is directly proportional to bond order, so C\(_2\) has a higher bond energy than Li\(_2\).

15. Which of the following species does not exhibit resonance?
   a. SO\(_3\)
   b. PCl\(_5\)
   c. HCO\(_2\)
   d. C\(_6\)H\(_6\)

16. At constant temperature and pressure, the volume of a gas will increase as the number of moles increases. Who's law is this?
   a. Pauli's
   b. Charles's
   c. Boyle's
   d. Avogadro's

17. A gas is contained in a flexible, 4.7 L container. The temperature of the gas is increased from 25 °C to 50 °C, and the pressure is decreased from 760 Torr to 730 Torr. What is the new volume of the gas?
   a. 5.3 L
   b. 9.7 L
   c. 5.8 L
   d. 6.5 L

   \[ V_1 = 4.7 \text{ L}, \quad V_2 = ? \]

   \[ T_1 = 25 + 273 = 298 \text{ K}, \quad T_2 = 323 \text{ K} \]

   \[ P_1 = 760 \text{ Torr} = 1 \text{ atm}, \quad P_2 = 730 \text{ Torr} = .96 \text{ atm} \]

   \[ P_1 \times V_1 / T_1 = P_2 \times V_2 / T_2 \]

   \[ V_2 = (P_1 \times V_1 \times T_2) / (T_1 \times P_2) = (1 \text{ atm} \times 4.7 \text{ L} \times 323 \text{ K}) / (298 \text{ K} \times .96 \text{ atm}) = 5.3 \text{ L} \]

18. 3.5 grams of a gas is held in a 1.13 L container at 25 °C and 2 atm. What is the molecular weight of the gas? Which molecule could this gas be?
   a. 40 g/mol; Ar
   b. 70 g/mol; Cl\(_2\)
   c. 4 g/mol; He
   d. 38 g/mol; F\(_2\)

   \[ g = 3.5 \text{ g} \]

   \[ V = 1.13 \text{ L} \]

   \[ T = 298 \text{ K} \]

   \[ P = 2 \text{ atm} \]

   \[ MW = gRT/PV = (3.5 \text{ g} \times .082 \text{ Latm/Kmol} \times 298 \text{ K}) / (2 \text{ atm} \times 1.13 \text{ L}) = 37.8 \text{ g/mol} \]

19. If the reaction goes to completion, what is the maximum number of moles that can be
obtained by reacting 5.00 L of H₂(g) with 2.00 L of N₂(g)? Assume STP for the reactants and products.

3 H₂ + N₂ → 2 NH₃

a. .178 mol  
b. .149 mol  
c. 1.63 mol  
d. 1.95 mol

moles of H₂ = (1 atm * 5.00 L)/(.082 Latm/molK * 273 K) = .223 mol
moles of N₂ = (1 atm * 2.00 L)/(.082 Latm/molK * 273 K) = .089 mol

.223 mol of H₂ (2 mol NH₃/3 mol H₂) = .149 mol NH₃  
.089 mol of N₂ (2 mol NH₃/1 mol of N₂) = .178 mol of NH₃

The maximum number of moles of NH₃ that can be obtained is .149 mol. All of the hydrogen will react, but there will be some remaining nitrogen gas.

20. If molecule A has a molecular weight of 127.5 g/mol and molecule B has a molecular weight of 120.2 g/mol, how many times faster will molecule B travel than molecule A?
   a. 1.30  
   b. 1.03  
   c. .971  
   d. .943

\[ \frac{m_1v_1}{v_2} = \frac{m_2v_2}{v_1} \]
\[ \frac{v_1}{v_2} = (\frac{m_2}{m_1})^{1/2} = (\frac{120.2}{127.5})^{1/2} = .971 \]
\[ v_1 = .971 v_2 \]
\[ v_2 = (1/.971) v_1 = 1.03 v_1 \]

Travis (that's me), Question Types 21-30.

21. Ranking non-ideality of gases

Rank the following gases from most to least ideal in terms of the van der Waal coefficient b:
   CO, N₂O, HF, H₂O₂.
   1. HF > CO > N₂O > H₂O₂
   2. H₂O₂ > HF > CO > N₂O
   3. HF > CO > H₂O₂ > N₂O
   4. CO > HF > H₂O₂ > N₂O

The van der Waal coefficient b is the "excluded molar volume" of a gas - it is an empirically determined value that relates to the size of the gaseous particles. This should be ranked based on molecular weight. Keeping in mind that kinetic molecular theory assumes gases are infinitely small, the most ideal species will be the smallest.

22. Gas non-ideality theory

Which of the combinations of V, n and T below would behave the most ideally?
   1. V = 2 L, n = 0.1 moles, T = 250 K
   2. V = 2 L, n = 0.5 moles, T = 100 K
   3. V = 10 L, n = 0.5 moles, T = 250 K
   4. V = 10 L, n = 0.1 moles, T = 500 K
   5. V = 2 L, n = 0.1 moles, T = 500 K

Conditions that favor ideality are low pressure, low density and high temperature.

23. IMF theory

Which of the following best explains all intermolecular forces?
   1. Electrostatic attractions between opposite charges.
   2. The capacity of molecules to form instantaneous dipoles.
   3. The tendency of ions to arrange themselves in lattices.
4. The large charge density that occurs when hydrogen is bonded to a very electronegative atom. Of all the various types of IMF, the thing they have in common is Coulombic attraction between regions of positive and negative charge.

24. Assigning IMF to molecules
Which of the following species exhibit hydrogen bonding?
   I. CH$_2$O
   II. CH$_3$OH
   III. CH$_3$COOH
   1. I only
   2. II only
   3. III only
   4. I and II
   5. I and III
   6. II and III
   7. I, II and III
Species I (CH$_2$O, aka methanal aka formaldehyde), has no hydrogen atoms covalently bonded to a highly electronegative atom.

25. Assigning IMF to molecules
For which of the following species are London forces significant?
   1. NH$_3$
   2. CH$_2$F$_2$
   3. O$_3$
   4. SF$_6$
All of the species have London forces, but all except SF$_6$ also have some other stronger IMF, such as dipole-dipole or hydrogen bonding.

26. Defining physical properties
Which of the following describes a fluid's ability to resist flow?
   1. mucilage
   2. viscosity
   3. surface tension
   4. capillary action
   5. vapor pressure
Viscosity is a measure of a fluid's internal "friction," or the reluctance of individual molecules in the fluid to move past one another or away from one another.

27. Ranking physical properties by IMF
Rank the following species from highest to lowest vapor pressure: HF, H$_2$O, NH$_3$
   1. NH$_3$ > HF > H$_2$O
   2. HF > H$_2$O > NH$_3$
   3. H$_2$O > NH$_3$ > HF
   4. NH$_3$ > H$_2$O > HF
This is pure memorization. Ammonia has the weakest hydrogen bonding of the three species, and consequently the lowest boiling point and highest vapor pressure. Next is HF and finally water which is strongest.

28. Ranking physical properties by IMF
Rank the following species from least to greatest viscosity: CH$_4$, C$_4$H$_{10}$, CH$_3$F, CF$_4$.
   1. CH$_4$ < C$_4$H$_{10}$ < CH$_3$F < CF$_4$
   2. CH$_4$ < C$_4$H$_{10}$ < CF$_4$ < CH$_3$F
   3. C$_4$H$_{10}$ < CH$_4$ < CH$_3$F < CF$_4$
4. CH₃F < C₄H₁₀ < CH₄ < CF₄
5. C₄H₁₀ < CH₄ < CF₄ < CH₃F
Methane, butane and tetrafluoromethane area all non-polar and should be ranked according to size (molecular weight). Fluoromethane is polar.

29. Ranking physical properties by IMF
Rank the following species from highest to lowest boiling point: H₂Te, H₂S, H₂O, H₂Se
1. H₂O > H₂S > H₂Se > H₂Te
2. H₂O > H₂Se > H₂Te > H₂S
3. H₂O > H₂Te > H₂S > H₂Se
4. H₂O > H₂Te > H₂Se > H₂S
The greater polarizability and dispersion forces of large atoms such as Se and Te, leads to stronger intermolecular forces in the species above that contain them. Water is obviously the largest because of its strong hydrogen bonding.

30. Assigning type of solid to compounds
Which of the species below is not covalent network?
1. graphite
2. dry ice
3. diamond
4. quartz
Dry ice, solid carbon dioxide, is a molecular solid. Graphite and diamond are both covalent networks formed by carbon and quartz is a covalent network with a unit formula of SiO₂.