1. My answers for this Chemistry 102 exam should be graded with the answer sheet associated with:

   a) Form A  b) Form B  c) Form C  d) Form D  e) Form E

2. At STP, 1.0 L of N₂(g) reacts completely with 3.0 L of F₂(g) to produce 2.0 L of a product gas. What is the formula of the product gas?
   Since P and T constants, volume is directly related to moles (\text{Va}N) so balanced equations give both mole ratios as well as volume ratios.
   \( \text{Let } \text{N}_x\text{F}_y = \text{formula of product gas} \)

3. In the early development of rockets, a common fuel mixture consisted of reacting hydrazine (\text{N}_2\text{H}_4) with dinitrogen tetroxide (\text{N}_2\text{O}_4), to produce a nitrogen gas and water vapor:
   \[ 2\text{N}_2\text{H}_4(l) + \text{N}_2\text{O}_4(l) \rightarrow 3\text{N}_2(g) + 4\text{H}_2\text{O}(g) \]
   If 100.0 g of \text{N}_2\text{H}_4 and 175.0 g of \text{N}_2\text{O}_4 are reacted by the above reaction, what mass of nitrogen can be produced? The molar masses of the reactants and products are: \text{N}_2\text{H}_4, 32.05 \text{g/mol}; \text{N}_2, 28.02 \text{g/mol}; \text{H}_2\text{O}, 18.02 \text{g/mol}.
   Since \text{N}_2\text{H}_4 produces the smallest quantity of \text{N}_2, \text{N}_2\text{H}_4 is limiting.
   a) 160.0 g  b) 87.43 g  c) 53.29 g  d) 106.6 g  e) 131.1 g

4. Consider two 1.0 L containers: container A contains 0.50 mol of Ne(g) at 25°C and container B contains 0.50 mol of He(g) at 50°C. Which of the following statements (a-c) is/are true concerning these two containers? Since the container is at the higher temperature, it has the larger average KE.
   a) The average kinetic energy of the Ne atoms in container A is larger than the average kinetic energy of the He atoms in container B.
   b) The Ne atoms in container A collide with the walls of the container more frequently than the He atoms in container B.
   c) The pressure in container A is larger than the pressure in container B.
   d) All of the above statements (a-c) are true.  e) None of the above statements (a-c) are true.

5. Rank the following substances in order of increasing boiling point (lowest boiling point to highest boiling point) for hydrogen bonding so it has the next highest boiling point. HCl and Ar are about the same molar mass, so each has about equal strength London dispersion forces. But the H-Cl bond is polar, so HCl has a polar molecule which exhibits additional dipole forces.
   a) HF < LiF < HCl < Ar  b) Ar < HCl < HF < LiF  c) Ar < HF < LiF < HCl  d) Ar < HF < HCl < LiF  e) HF < Ar < HCl < LiF

   LiF = Ionic compound, has strongest forces so boils at highest T. HF exhibits.
6. One of the following substances is a solid at 25°C and 1 atm, while the others are gases at 25°C and 1 atm. Which substance is a solid at 25°C and 1 atm?
   a) He
   b) Ne
   c) H₂
   d) Cl₂
   e) I₂

   Because I₂ is the largest compound (largest molar mass), I₂ has the strongest Intermolecular forces, I₂ is the solid at 25°C, while the others with weaker Intermolecular forces are gases at 25°C.

7. An unknown gas has an effusion rate that is 2.0 times faster than that of SO₂(g). Which of the following is the unknown gas? 5.00 °C
   a) H₂
   b) He
   c) He³⁺
   d) CH₄
   e) O₂

   Solving: \( \frac{M_x}{M_{SO₂}} = \sqrt{64} \), \( M_x = 16 \) g/mol. CH₄ has a molar mass of 16 g/mol.

8. A 50.0 mL flask containing N₂(g) at 2.50 atm and a 75.0 mL flask containing Ar(g) at 325 torr are connected by a stopcock (see the illustration below). Treat each gas separately, and calculate the partial pressures. For each gas, \( N + T \) are constant, so \( \frac{P_1V_1}{V_2} = \frac{P_2V_2}{V_1} \)

   For N₂:
   \( P_2 = \frac{P_1V_1}{V_2} = \frac{2.50 \text{ atm}(50.0 \text{ mL})}{125.0 \text{ mL}} \)
   \( P_2 = 1.00 \text{ atm} = 760 \text{ torr} \)

   For Ar:
   \( P_2 = \frac{P_1V_1}{V_2} = \frac{325 \text{ torr}(75.0 \text{ mL})}{125.0 \text{ mL}} \)

   After the stopcock valve between the two flasks is opened and the gases have time to mix completely, what is the total pressure inside the entire system? Assume temperature is constant.

   \( P_{\text{tot}} = P_{N₂} + P_{Ar} = 760 + 195 = 955 \text{ torr} \)

9. Dimethyl ether (CH₃–O–CH₃) and ethanol (CH₃CH₂OH) have the same molecular formula (C₂H₅O₂), but very different physical properties. For example, dimethyl ether has a vapor pressure of 400 torr at -37.8°C, while ethanol has a vapor pressure of 400 torr at 63.5°C. Which of the following statements (a–d) about these two compounds is false?

   a) Increasing the temperature will increase the vapor pressure of both liquids. –true for all substances
   b) Intermolecular attractive forces are stronger in (liquid) ethanol than in (liquid) dimethyl ether. –Ethanol has H-bonding, dimethyl ether cannot.
   c) The normal boiling point of dimethyl ether will be higher than the normal boiling point of ethanol. –Because ethanol has the stronger Intermolecular forces, it will have the higher boiling point.
   d) The reason that the temperature at which the vapor pressure equals 400 torr is higher for ethanol than for dimethyl ether is that there is relatively strong hydrogen bonding in ethanol, unlike in dimethyl ether.
   e) None of these statements (a–d) is false.

   Ethanol, with the –OH group, can form the relatively strong hydrogen bonding intermolecular forces. Dimethyl ether is a polar compound, so it exhibits dipole forces, but these dipole forces are much weaker than hydrogen bonding.
CHEMISTRY 102
HOUR EXAM II

10. Which of the following reactions (a-d) is incorrectly classified?

- **Yes**
  a) \( \text{Na}_2\text{Cu}_3\text{O}_4\text{(aq)} + \text{ZnCl}_2\text{(aq)} \rightarrow 2 \text{NaCl(aq)} + \text{ZnCO}_3\text{(s)} \) precipitation reaction
  b) \( 2 \text{KClO}_3\text{(s)} \rightarrow 2 \text{KCl(s)} + 3 \text{O}_2\text{(g)} \) decomposition reaction
  c) \( \text{Mg(s)} + 2 \text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)} \) single displacement reaction
  d) \( \text{H}_3\text{PO}_4\text{(aq)} + 3 \text{KOH(aq)} \rightarrow 3 \text{H}_2\text{O(l)} + \text{K}_3\text{PO}_4\text{(aq)} \) acid-base reaction
- **NO**
  e) All of the above reactions (a-d) are correctly classified.

11. Consider the following reaction:

\[ 2 \text{Cu(s)} + \text{S(s)} \rightarrow \text{Cu}_2\text{S(s)} \]

If the reaction has a 73.0% yield, what mass of copper is needed to obtain an actual yield of 10.0 g of \( \text{Cu}_2\text{S} \)?

**Theoretical mass of \( \text{Cu}_2\text{S} \) = 10.0 g \( \text{Cu}_2\text{S} \) actual \times \frac{100.0 g \text{Cu}_2\text{S theoretical}}{73.0 g \text{Cu}_2\text{S actual}} = 13.7 g \text{Cu}_2\text{S} \)

- a) 3.99 g \( \text{Cu} \)
- b) 5.47 g \( \text{Cu} \)
- c) 7.99 g \( \text{Cu} \)
- d) 10.9 g \( \text{Cu} \)
- e) 15.2 g \( \text{Cu} \)

12. A compound containing only \( \text{Zn}, \text{O}, \text{P} \) is 50.80% \( \text{Zn} \) and 16.04% \( \text{P} \) by mass. What is the empirical formula of the compound? Assume 100.00 g compound.

- a) \( \text{Zn}_2\text{O}_3\text{P}_3 \)
- b) \( \text{Zn}_5\text{O}_3\text{P}_3 \)
- c) \( \text{Zn}_2\text{O}_3\text{P}_3 \)
- d) \( \text{Zn}_5\text{O}_3\text{P}_3 \)
- e) \( \text{Zn}_3\text{O}_3\text{P}_3 \)

13. Which of the following statements is false concerning ideal gases?

- a) For a mixture of gases, the total pressure is the sum of the partial pressures of all the gases present. This is Dalton's law of partial pressures.
- b) At constant \( P \) and \( n \), a plot of volume (L) vs. temperature (K) is linear. \( V = \text{constant} \) is the form of \( y = mx + b \), so a straight line is plotted.
- c) For constant \( V \) and \( T \), the molar mass of a gas sample is directly related to the pressure of the gas sample. \( P = nRT \).
- d) For constant \( n \) and \( T \), as the volume of a gas sample increases, the pressure of the gas decreases. \( PV = \text{constant} = nRT \), this is Boyle's law. \( P \) and \( V \) are inversely related.
- e) At constant \( P \) and \( T \), a 2.0 L sample of \( \text{N}_2\text{(g)} \) contains twice the number of molecules as a 1.0 L sample of \( \text{SO}_3\text{(g)} \). At constant \( P + T \), 2.0 L of \( \text{N}_2 \) will contain twice the number of molecules as 1.0 L of \( \text{SO}_3 \).

\[ \frac{V_{\text{N}_2}}{V_{\text{SO}_3}} = \frac{N_{\text{N}_2}}{N_{\text{SO}_3}} \]
Nonelectrolytes will be the covalent compounds which are not acids. This is FeCl₃ and CO₂. All the other compounds are strong electrolytes. LiOH and NH₄NO₃ are soluble ionic compounds, while HNO₃ is a strong acid.

There are no weak acids (weak electrolytes) in this list.

a) 0 (None are nonelectrolytes.)
b) 1
c) 2

d) 3

e) 4

15. All the arsenic in 1.22 g of a pesticide was converted to AsO₄³⁻ by suitable chemical treatment. All the AsO₄³⁻ was then reacted with Ag⁺ to form Ag₃AsO₄ as a precipitate. It took 50.0 mL of 0.0500 M AgNO₃ to precipitate all the AsO₄³⁻. Assuming 100% yield, what is the mass percent of As in the pesticide?

\[
\text{mass As} = \frac{0.0500 \text{ L} \times 0.0500 \text{ mol As} \times \frac{1 \text{ mol Ag₃AsO₄}}{3 \text{ mol Ag}^+} \times \frac{1 \text{ mol As}}{1 \text{ mol Ag₃AsO₄}} \times \frac{74.92 \text{ g As}}{1 \text{ mol As}}}{1.22 \text{ g pesticide}} = 0.06243 \text{ g As}
\]

\[
\text{mass As} = \frac{0.06243 \text{ g As}}{1.22 \text{ g pesticide}} \times 100 = 5.129 \%
\]

16. You have a 1.0 M solution of aqueous HF. What ions and/or molecules are present in this solution? HF is a weak acid, so it is a weak electrolyte.

a) Only H⁺ ions and F⁻ ions are present.

b) Only HF molecules and H₂O molecules are present.

c) HF molecules, H⁺ ions, F⁻ ions, and H₂O molecules are all present.

d) Only H⁺ ions, F⁻ ions, and H₂O molecules are present.

e) Only HF molecules are present.

17. Explosives are usually effective if they produce a large number of gaseous molecules as products. Nitroglycerin, for example, detonates according to the equation:

\[
4 \text{ mol nitro} + 12 \text{ mol } H₂ \text{ gas} + 6 \text{ mol } H₂O = 29 \text{ mol gas}
\]

If 0.0400 mol of nitroglycerin explodes in a 10.0 L rigid container, calculate the total pressure of all gases present assuming the temperature is 500 °C.

\[
\text{Partial pressure of nitro} = \frac{0.0400 \text{ mol nitro} \times 4 \text{ mol gas}}{29 \text{ mol gas}} = 0.290 \text{ atm gas total}
\]

\[
\text{Partial pressure of H₂O} = \frac{0.08206 \times 773K}{10.0 \text{ L}} = 1.84 \text{ atm}
\]

18. Consider the following unbalanced reaction:

\[
\text{HCl(g)} + \frac{1 \text{ mol O₂}}{4 \text{ mol HCl}} \rightarrow \text{H₂O(g)} + \text{Cl}_2(g)
\]

How many grams of O₂ are necessary to react completely with 20. mol of HCl?

a) 640 g H₂O
b) 60 g O₂
c) 320 g O₂
d) 2600 g O₂
e) 1300 g O₂
19. You take a 1.00 g sample of aspirin (a compound consisting solely of carbon, hydrogen, and oxygen), burn it in excess oxygen, and collect 2.20 g of carbon dioxide and 0.400 g of water. The molar mass of aspirin is between 160 and 190 g/mol. What is the mass percent of oxygen in aspirin?

\[
\text{mass \% O} = \frac{0.3548 \text{ g O}}{1.00 \text{ g aspirin}} \times 100 = 35.5\% \text{ O}
\]

(a) 35.5%, (b) 23.5%, (c) 30.0%, (d) 16.4%, (e) 47.0%

20. You take a 1.00 g sample of aspirin (a compound consisting solely of carbon, hydrogen, and oxygen), burn it in excess oxygen, and collect 2.20 g of carbon dioxide and 0.400 g of water. The molar mass of aspirin is between 160 and 190 g/mol. Which of the following is the molecular formula of aspirin?

- \( \text{C}_6\text{H}_6\text{O}_3 \) (a)
- \( \text{C}_9\text{H}_8\text{O}_4 \) (b)
- \( \text{C}_7\text{H}_8\text{O}_3 \) (c)
- \( \text{C}_6\text{H}_5\text{O}_2 \) (d)
- \( \text{C}_12\text{H}_16\text{O}_7 \) (e)

So 1.00 g aspirin contains 0.6004 g C, 0.0475 g H, and 0.3548 g O (see above calculations).

21. When 1.00 L of 1.00 M \( \text{H}_3\text{PO}_4 \) is reacted with 1.00 L of 1.00 M \( \text{Ca(OH)}_2 \), what mass of water is produced (assuming 100% yield)?

\[
2\text{H}_3\text{PO}_4(aq) + 3 \text{Ca(OH)}_2(aq) \rightarrow 6\text{H}_2\text{O}(l) + \text{Ca}_3\text{(PO}_4)_2(s)
\]

If \( \text{H}_3\text{PO}_4 \) is the limiting reagent:

- a) 6.00 g H\(_2\)O
- b) 9.01 g H\(_2\)O
- c) 18.0 g H\(_2\)O
- d) 36.0 g H\(_2\)O
- e) 54.0 g H\(_2\)O

If \( \text{Ca(OH)}_2 \) is the limiting reagent:

- d) 36.0 L \( \text{H}_2\text{O} \)
- e) 54.0 L \( \text{H}_2\text{O} \)

22. A binary compound is composed of an unknown element X and hydrogen. The compound has three times as many H atoms as X atoms in the molecular formula and is 80.0% X by mass. Which of the following could be the element X? Empirical and molecular formulas have the same mass percent.

- a) N
- b) O
- c) B
- d) Be
- e) He

Let \( M = \text{molar mass of X} \), \( \frac{0.800}{M + 3x} \text{ mass of X in empirical formula} \). Let \( \text{M + 3x} = \text{molar mass of formula} \). Let \( \text{M = 2.40/0.2 = 12.0 g/mol} \). Molar mass of \( \text{Mg} \) was calculated.

23. What volume of a 0.300 M \( \text{CaCl}_2 \) solution is needed to prepare 240. mL of a 0.400 M \( \text{Ca}^{2+} \) solution?

\[
\text{Ca}^{2+} \text{(aq)} \rightarrow \text{Ca}^{2+} \text{(aq)} + 2\text{Cl}^{-} \text{(aq)}
\]

- a) 40.0 mL
- b) 80.0 mL
- c) 120. mL
- d) 240. mL
- e) 480. mL

\[
0.240\text{ L} \times \frac{0.100\text{ mol} \text{Cl}^{-}}{1\text{ mol} \text{CaCl}_2} \times \frac{1\text{ mol} \text{Ca}^{2+}}{2\text{ mol} \text{Cl}^{-}} \times \frac{1\text{ L} \text{CaCl}_2}{0.300\text{ mol} \text{CaCl}_2} = 0.0400\text{ L}
\]

\[
= 40.0\text{ mL}
\]
24. The five most abundant gases in a sample of air are N₂, O₂, Ar, CO₂, and Ne. Consider five separate 2.5 L samples of each individual gas at 352 K and 6.25 atm. Which gas sample would behave least ideally? (a) N₂ (b) CO₂ (c) Ar (d) O₂ (e) Ne

25. Consider the following balanced equation between gas X to form gas Y: \[2X(g) \rightarrow Y(g)\]

In both containers, mass doesn't change because \[\rho = \frac{\text{mass}}{\text{volume}}\] in order to change the density, the volume of the container must change. Note that as this reaction occurs, moles of gas decrease by a factor of 2.

Equal moles of X are placed in two separate containers. One container is rigid so the volume cannot change; the other container is flexible (like a balloon) so the volume changes in order to keep the internal pressure equal to the external pressure. The above reaction is run in each container. Which of the following is true concerning the pressure and density of the gas inside each container as reactants are converted to products?

Assume a constant external pressure and assume a constant temperature.

- (a) Rigid container: Pressure decreases, density is constant
- (b) Rigid container: Pressure is constant, density is constant
- (c) Rigid container: Pressure decreases, density increases
- (d) Rigid container: Pressure is constant, density is constant
- (e) Flexible container as \( n \) decreases, volume decreases in order to keep pressure constant

Concentration of \( \text{Fe}^{3+} \) ions in the final solution after precipitate formation is complete. From above, 0.0033 mol Fe(OH)₃ precipitate forms. This precipitate contains 0.0033 mol Fe³⁺ (from formula).

- (a) 0.00 M
- (b) 0.033 M
- (c) 0.040 M
- (d) 0.056 M
- (e) 0.067 M

Fe(NO₃)₃(s) + 3 KOH(s) → Fe(OH)₃(s) + 3 KNO₃(s)

Consider the following information for the next two questions.

\[ \text{mol Fe(NO₃)₃} = 0.2000 \times 0.10 \text{ mol} = 0.0200 \text{ mol Fe(NO₃)₃} \]

When 200.0 mL of 0.10 M Fe(NO₃)₃ is mixed with 100.0 mL of 0.10 M KOH, a precipitate forms.

\[ \text{mol KOH} = 0.10 \times 0.10 = 0.010 \text{ mol KOH} \]

If Fe(NO₃)₃ is limiting: \( 0.0200 \text{ mol Fe(NO₃)₃} \times \frac{1 \text{ mol Fe(OH)₃}}{1 \text{ mol Fe(NO₃)₃}} = 0.0200 \text{ mol Fe(OH)₃} \]

If KOH is limiting: \( 0.0100 \text{ mol KOH} \times \frac{3 \text{ mol Fe(OH)₃}}{3 \text{ mol KOH}} = 0.0033 \text{ mol Fe(OH)₃} \]

26. How many moles of precipitate can form in this reaction?

- (a) 0.0033 mol
- (b) 0.0050 mol
- (c) 0.010 mol
- (d) 0.020 mol
- (e) 0.030 mol

27. Calculate the concentration of \( \text{Fe}^{3+} \) ions in the final solution after precipitate formation is complete. From above, 0.0033 mol Fe(OH)₃ precipitate forms. This precipitate contains 0.0033 mol Fe³⁺ (from formula).

- (a) 0.00 M
- (b) 0.033 M
- (c) 0.040 M
- (d) 0.056 M
- (e) 0.067 M

\[ \text{mol Fe}^{3+} \text{ initially} = 0.0200 \text{ mol Fe(NO₃)₃} \times \frac{\text{mol Fe}^{3+}}{\text{mol Fe(NO₃)₃}} = 0.0200 \text{ mol Fe}^{3+} \]

\[ \text{mol Fe}^{3+} \text{ in solution} = 0.0200 \text{ mol Fe}^{3+} \text{ initially} - 0.0033 \text{ mol Fe}^{3+} \text{ used up to form precipitate} \]

\[ M_{\text{Fe}^{3+}} = \frac{0.0167 \times 1 \text{ mol Fe}^{3+}}{(0.200 + 0.100) \text{ L}} = 0.056 \text{ M} \]
28. If you dissolve 0.0200 mol of barium hydroxide in enough water to make 250. mL of solution, what volume of 0.100 M hydrochloric acid is required to react completely with the barium hydroxide?

\[
\text{Ba(OH)\textsubscript{2}(aq)} + 2\text{HCl(aq)} \rightarrow 2\text{H}_2\text{O(l)} + \text{BaCl\textsubscript{2}(aq)}
\]

\[
0.0200 \text{ mol Ba(OH)\textsubscript{2}} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Ba(OH)\textsubscript{2}}} \times \frac{1 \text{ L HCl}}{0.100 \text{ mol HCl}} = 0.400 \text{ L}
\]

a) 100. mL  
   b) 200. mL  
   c) 300. mL  
   d) 400. mL  
   e) 500. mL

29. An unknown gas has an empirical formula of CH\textsubscript{2}. The density of the unknown gas is 2.19 times greater than the density of O\textsubscript{2}(g) at the same temperature and pressure. Which of the following is the molecular formula of the unknown gas?

- a) CH\textsubscript{3}  
- b) C\textsubscript{2}H\textsubscript{4}  
- c) C\textsubscript{3}H\textsubscript{6}  
- d) C\textsubscript{4}H\textsubscript{8}  
- e) C\textsubscript{5}H\textsubscript{10}

29. Let \( M_g = \) molar mass of unknown

\[
2.19 \times \text{density of O}_2 = \frac{M_g}{32.0} = \frac{M_o}{2.0}
\]

a) CH\textsubscript{3}  
   b) C\textsubscript{2}H\textsubscript{4}  
   c) C\textsubscript{3}H\textsubscript{6}  
   d) C\textsubscript{4}H\textsubscript{8}  
   e) C\textsubscript{5}H\textsubscript{10}

30. Which of the following compounds is expected to have the highest vapor pressure at some temperature, T? Highest vapor pressure = weakest Intermolecular forces.

- a) CH\textsubscript{3}  
- b) SiH\textsubscript{4}  
- c) NH\textsubscript{3}  
- d) H\textsubscript{2}O  
- e) HF

Both CH\textsubscript{4} and SiH\textsubscript{4} are nonpolar, so only have London-dispersion forces. Since CH\textsubscript{4} is smaller (smaller molar mass), CH\textsubscript{4} has weakest intermolecular forces and highest vapor pressure.

31. Real gases do not always obey the ideal gas equation, \( PV = nRT \). Under which of these conditions will a gas behave most ideally?

- a) P = 1.0 atm, T = 273 K  
- b) P = 0.50 atm, T = 200 K  
- c) P = 0.50 atm, T = 400 K  
- d) P = 2.0 atm, T = 400 K  
- e) P = 2.0 atm, T = 200 K

A gas behaves most ideal at high temperatures and low pressures. Answer c has lowest pressure and highest temperature, so it is correct.

32. 25.0 mL of 0.50 M Pb(NO\textsubscript{3})\textsubscript{2} is added to four separate beakers containing:

- Beaker I: 50.0 mL of 0.25 M NaCl
- Beaker II: 50.0 mL of 0.25 M NaOH
- Beaker III: 50.0 mL of 0.25 M Na\textsubscript{2}PO\textsubscript{4}
- Beaker IV: 50.0 mL of 0.25 M Na\textsubscript{2}SO\textsubscript{4}

After addition of the Pb(NO\textsubscript{3})\textsubscript{2} solution, in how many of the beakers will a precipitate form?

- a) 0 (none)  
- b) 1  
- c) 2  
- d) 3  
- e) 4 (all)

All of these solutions will form a precipitate when Pb\textsuperscript{2+} is added in.