Please write your answers neatly in the spaces provided. Please use a blue or black ink pen. You may use a non-programmable calculator. You must show your work to receive full credit. Include units in your work and answer if needed and pay attention to significant figures. Place a box around your final answer. There are 36 questions, some with multiple parts. The periodic table is at the end. You may detach it.

Academic Integrity Pledge

During the exam I will

- turn off my cell phone and put it away (out of sight and not on my person)
- close all books, notebooks, etc. and put them under the seat in which I sit
- keep my eyes down and focused on my own paper
- keep my answers covered
- sit in the area assigned to my section

I will stop writing when time is called.

I will hand in my paper when told to do so.

I understand that the minimum consequence of any behavior contrary to this pledge is that I will receive a zero on this exam that will not be replaced by the percent earned on my final exam.

Name (sign)______________________________

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**Scoring**

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Total: ____________________________

R = 0.08206 L atm/mol K
1 mol of any gas at STP occupies 22.4 L
1 atm = 760 mm Hg
1 atm = 101,325 Pa = 101.3 kPa
1 atm = 760 torr
STP is 1 atm and 273 K
Questions 1-8 are worth 4 points each.

1. Classify each of the following as a pure substance or a mixture. If it is a pure substance, classify it as an element or a compound. If it is a mixture, classify it as homogeneous or heterogeneous.
   - helium gas: pure substance, element
   - chocolate chip cookie: mixture, heterogeneous
   - silver chloride: pure substance, compound
   - coffee: mixture, homogeneous

2. Determine whether each of the following changes is physical or chemical.
   - A balloon filled with hydrogen gas explodes upon contact with a spark. chemical
   - The liquid propane in a barbecue evaporates away because the user left the valve open. physical

3. When 56.0 J of heat are added to 11.0 g of a liquid, its temperature rises from 10.4 °C to 12.7 °C. What is the heat capacity of the liquid?
   \[ Q = \Delta m \Delta T \]
   \[ \Delta T = 12.7 - 10.4 = 2.3 \]
   \[ s = \frac{Q}{m \Delta T} = \frac{56.0}{(11.0)(2.3)} = 2.2 \text{ J/g°C} \]

4. Would you expect the following elements to gain or lose electrons in chemical changes.
   - potassium: lose
   - sulfur: gain
   - fluorine: gain
   - copper: lose

5. Write the electron configuration for each of the following elements in the ground state. You may use the noble gas abbreviation.
   - Cl: \( 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5 \) or \([Ne]\ 3s^2\ 3p^5\)
   - Mn: \([Ar]\ 4s^2\ 3d^5\)
6. Write the full electron configuration for each of the following ions. Do not use a Noble gas abbreviation.

\[
\text{Ca}^{2+} \quad 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \\
\text{Se}^{2-} \quad 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^{10} \ 4p^6
\]

7. Describe the bonding in each of the following. Use words such as ionic, non-polar covalent, or polar covalent.

\[
\text{HBr (g)} \quad \text{polar covalent} \\
\text{MgF}_2 \quad \text{ionic}
\]

8. Complete and balance the following equation:

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

The remaining questions are worth 6 points each.

9. Name the following compounds:

a. LiIO\(_4\) \quad \text{lithium periodate} \\
b. FeCl\(_3\) \quad \text{iron (III) chloride} \\
c. PBr\(_3\) \quad \text{phosphorus tribromide} \\
d. Cu\(_2\)SO\(_3\) \quad \text{copper(1) sulfite} \\
e. Ag\(_3\)PO\(_4\) \quad \text{silver phosphate} \\
f. HNO\(_2\) \quad \text{nitrous acid}
10. Write formulas for the following compounds:
   a. magnesium acetate \( \text{Mg} \left( \text{C}_2\text{H}_3\text{O}_2 \right)_2 \)
   b. ammonium nitrate \( \text{NH}_4 \text{NO}_3 \)
   c. potassium permanganate \( \text{KMnO}_4 \)
   d. calcium hydroxide \( \text{Ca(OH)}_2 \)
   e. cobalt(II) hydrogen carbonate \( \text{Co(HCO}_3\text{)}_2 \)
   f. nickel(II) acetate \( \text{Ni(C}_2\text{H}_3\text{O}_2\text{)}_2 \)

11. Draw a reasonable Lewis structure for each of the following. Be sure to include unshared pairs of electrons where necessary. **Describe the molecular shape (geometry).**

   \( \text{NF}_3 \)
   \[
   \begin{array}{c}
   \cdot F \\
   \cdot N \\
   \cdot F \\
   \cdot F
   \end{array}
   \]

   \( \text{SiH}_4 \)
   \[
   \begin{array}{c}
   \cdot H \\
   \cdot \text{Si} \\
   \cdot H \\
   \cdot H
   \end{array}
   \]
   tetrahedral

12. Write and balance the equation showing the reaction between copper metal and aqueous sulfuric acid to form aqueous copper (II) sulfate, sulfur dioxide gas and water.

   \[
   \text{Cu(s)} + 2 \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4(\text{aq}) + \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}
   \]

13. Write and balance the equation showing the reaction between nitrogen monoxide gas and hydrogen gas to form nitrogen gas and water vapor.

   \[
   2 \text{NO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}
   \]
14. BALANCE and CLASSIFY the following reactions. Use the standard choices: combination, decomposition, oxidation (combustion), single replacement (redox), double replacement - precipitation (DRP) or double replacement - neutralization (DRN).

\[ 2 \text{ C}_3\text{H}_7\text{OH (l)} + 9 \text{ O}_2 (g) \rightarrow 6 \text{ CO}_2 (g) + 8 \text{ H}_2\text{O (g)} \quad \text{oxidation combustion} \]

\[ 2 \text{ Co(NO}_3)_3 (aq) + 3 (\text{NH}_4)_2\text{S (aq)} \rightarrow \text{Co}_2\text{S}_3 (s) + 6 \text{NH}_4\text{NO}_3 (aq) \quad \text{double replace ppt} \]

15. Calculate the number of atoms in 8.095 grams of calcium. Ca = 40.08 amu

\[ 8.095 \text{ g Ca} \left( \frac{1 \text{ mol Ca}}{40.08 \text{ g Ca}} \right) \left( \frac{23 \text{ atoms}}{1 \text{ mol}} \right) = 1.216 \times 10^{23} \text{ atoms} \]

16. How many moles are in 1.54 g of Zinc? Zn = 65.38 amu

\[ 1.54 \text{ g Zn} \left( \frac{1 \text{ mol Zn}}{65.38 \text{ g}} \right) = 0.0236 \text{ mol Zn} \]

17. What is the mass (in grams) of 1.640 moles of K$_2$SO$_3$?

K = 39.10 amu, S = 32.07 amu, O = 16.00 amu

\[ 2 \left( \frac{39.10}{158.27} \right) = 78.20 \quad 1.640 \text{ mol} \left( \frac{158.27 \text{ g}}{1 \text{ mol}} \right) \quad = 259.60 \text{ g} \]

18. What is the molarity of a solution that is 321 g of CaCl$_2$ with a total volume of 1.45 L?

Ca = 40.08, Cl = 35.45

\[ \frac{321 \text{ g}}{110.98 \text{ g/mol}} = 2.89 \text{ mol} \quad M = \frac{\text{mol}}{\text{L}} = \frac{2.89 \text{ mol}}{1.45 \text{ L}} \quad = 1.99 \text{ M} \]
19. What mass in grams of solute does the following sample contain: 173 mL of 1.24 M KBr.

\[
0.173 \text{ L} \\
1.24 \text{ mol/L (0.173 L)} = 0.21452 \text{ mol (} \frac{119.009 \text{ g}}{\text{mol}} \text{)} = 25.5 
\]

20. If 75 mL of 0.211 M NaOH is diluted to a final volume of 125 mL, what is the concentration of NaOH in the diluted solution?

\[
M_1 V_1 = M_2 V_2 \\
(0.211)(75) = M_2 (125) \\
0.127 = M_2 
\]

21. A compound (that smells like pineapple) is analyzed and found to contain 62.04 % carbon, 10.41 % hydrogen and 27.55 % oxygen (by mass). Calculate the empirical formula of this compound.

Atomic masses: C = 12.01 amu, H = 1.008 amu, O = 16.00 amu

\[
62.04 \text{ g C} \left( \frac{\text{mol C}}{12.01 \text{ g} } \right) = 5.166 \text{ mol C} \div 1.722 = 3 \\
10.41 \text{ g H} \left( \frac{\text{mol H}}{1.008 \text{ g} } \right) = 10.327 \text{ mol H} \div 1.722 = 6 \\
27.55 \text{ g O} \left( \frac{\text{mol O}}{16.00 \text{ g} } \right) = 1.722 \text{ mol O} \div 1.722 = 1 
\]

\[
C_3H_6O 
\]

22. Given the following balanced equation for the reaction:

\[
2 \text{ KI} + \text{Hg(NO}_3)_2 \rightarrow \text{HgI}_2 + 2 \text{ KNO}_3 
\]

Calculate the mass (in grams) of potassium iodide required to yield 2.78 g of mercury(II) iodide precipitate. Molar masses: KI = 166.00 g/mol; HgI₂ = 454.39 g/mol

\[
2.78 \text{ g HgI}_2 \left( \frac{\text{mol HgI}_2}{454.39 \text{ g}} \right) \left( \frac{2 \text{ mol KI}}{1 \text{ mol HgI}_2} \right) \left( \frac{166.00 \text{ g KI}}{\text{mol KI}} \right) = 2.03 \text{ g KI} 
\]
23. Given the following balanced equation for the reaction:

\[ 5 \text{C} + 2 \text{SO}_2 \rightarrow \text{CS}_2 + 4 \text{CO} \]

What is the theoretical yield (in grams) of \( \text{CS}_2 \) when 8.50 g of carbon are combined with 8.50 g of \( \text{SO}_2 \)? Masses: \( \text{C} = 12.01 \text{ amu} \); \( \text{SO}_2 = 64.07 \text{ g/mol} \); \( \text{CS}_2 = 76.15 \text{ g/mol} \)

\[
8.50 \text{ g C} \left( \frac{1 \text{ mol C}}{12.01 \text{ g C}} \right) \left( \frac{1 \text{ mol } \text{CS}_2}{76.15 \text{ g } \text{CS}_2} \right) = 10.8 \text{ g } \text{CS}_2
\]

\[
8.50 \text{ g } \text{SO}_2 \left( \frac{1 \text{ mol } \text{SO}_2}{64.07 \text{ g } \text{SO}_2} \right) \left( \frac{1 \text{ mol } \text{CS}_2}{2 \text{ mol } \text{SO}_2} \right) = 5.05 \text{ g } \text{CS}_2
\]

24. Given the following balanced equation for the reaction:

\[ 2 \text{NaN}_3 (s) + \text{spark} \rightarrow 2 \text{Na} + 3 \text{N}_2 \]

In the event of a car crash, the unstable compound in an air bag, NaN₃ decomposes explosively and fills the air bag with nitrogen gas in about 30 seconds. If an air bag contains 150.0 g of NaN₃, what is the volume of nitrogen gas produced at STP? Molar masses: \( \text{NaN}_3 = 65.02 \text{ g/mol} \); \( \text{N}_2 = 28.02 \text{ g/mol} \)

\[
150.0 \text{ g } \text{NaN}_3 \left( \frac{1 \text{ mol } \text{NaN}_3}{65.02 \text{ g } \text{NaN}_3} \right) \left( \frac{3 \text{ mol } \text{N}_2}{2 \text{ mol } \text{NaN}_3} \right) = 3.460 \text{ mol } \text{N}_2
\]

\[
3.460 \text{ mol } \text{N}_2 \left( \frac{22.4 \text{ L}}{1.00 \text{ mol}} \right) = 77.5 \text{ L}
\]

25. What pressure of hydrogen gas at 3.20 L volume and 22.0 °C could be produced by the reaction of 2.00 g of Al with excess HCl by the reaction: \( 2 \text{Al} + 6 \text{HCl} \rightarrow 2 \text{AlCl}_3 + 3 \text{H}_2 (g) \)?

\[
T = 295 \text{ K}
\]

\[
2.00 \text{ g Al} \left( \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \right) \left( \frac{3 \text{ mol } \text{H}_2}{2 \text{ mol Al}} \right) = 0.111 \text{ mol } \text{H}_2
\]

\[
P \cdot V = n \cdot R \cdot T
\]

\[
R = \frac{n \cdot R \cdot T}{V} = \left( 0.111 \text{ mol } \text{H}_2 \right) \left( 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right) \left( 295 \text{ K} \right)
\]

\[
= 0.840 \text{ atm}
\]
26. A gas occupies 340 mL at 273 K and 0.625 atm. What final temperature would be required to increase the pressure to 1.00 atm, the volume being held constant?

\[ \frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2} \]

\[ \frac{P_1}{T_1} = \frac{P_2}{T_2} \]

\[ T_2 = \frac{P_2 T_1}{P_1} \]

\[ = \frac{(1.00) (273)}{0.625} = 437 \text{ K} \]

27. Assuming that the pressure and quantity of a gas sample remain constant, what will the final volume of a 4.86 L sample of a gas originally at 281 °C be when heated to 400 °C?

\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

\[ V_2 = \frac{V_1 T_2}{T_1} \]

\[ = \frac{(4.86) (673)}{554} = 5.90 \text{ L} \]

28. How many moles of nitrogen gas will occupy a volume of 1.25 L at a pressure of 1.00 atm and a temperature of 200 °C?

PV = nRT

\[ n = \frac{PV}{RT} = \frac{(1.00)(1.25)}{(0.082057 \text{ L atm mol}^{-1} \text{ K}^{-1}) (473 \text{ K})} \]

\[ = 0.0322 \text{ mol} \]

29. How many mL of 0.00850 M Ca(OH)₂ solution are needed to react with 20.0 mL of 0.0120 M H₃PO₄ solution? Use the balanced equation: 2 H₃PO₄ + 3 Ca(OH)₂ → Ca₃(PO₄)₂ + 6 H₂O

H₃PO₄ = 97.99 g/mol; Ca(OH)₂ = 74.10 g/mol

\[
\text{H₃PO₄} \quad \text{Ca(OH)₂} \\
20.0 \text{ mL} \quad x \text{ mL} \\
0.0120 \text{ M} \quad 0.00850 \text{ M}
\]

\[
= \frac{0.0200 \text{ L}}{0.0120 \text{ mol L}^{-1} \text{ mol L}^{-1}} \times 3 \text{ mol} \text{ L}^{-1} \text{ mol L}^{-1} \times \frac{1 \text{ L} \text{ mol}^{-1} \text{ mol}^{-1}}{0.00850 \text{ mol}^{-1} \text{ mol}^{-1}}
\]

\[ = 0.0424 \text{ L} \]

or 42.4 mL
30. Commercial preparation of the once-popular dry cleaning solvent carbon tetrachloride (CCl₄) was by the reaction \( \text{CS}_2 + 2 \text{S}_2\text{Cl}_2 \rightarrow \text{CCl}_4 + 6 \text{S} \). How many grams of \( \text{S}_2\text{Cl}_2 \) are needed to prepare 38.4 grams of carbon tetrachloride. The molar masses are: \( \text{CS}_2 = 76.143 \text{ g/mol} \); \( \text{S}_2\text{Cl}_2 = 135.025 \text{ g/mol} \); \( \text{CCl}_4 = 153.822 \text{ g/mol} \); and \( \text{S} = 32.066 \text{ g/mol} \)

\[
38.4 \text{ g CCl}_4 \left( \frac{\text{mol CCl}_4}{153.822 \text{ g}} \right) \left( \frac{2 \text{ mol S}_2\text{Cl}_2}{1 \text{ mol CCl}_4} \right) \left( \frac{135.025 \text{ g}}{\text{mol S}_2\text{Cl}_2} \right) = 67.4 \text{ g S}_2\text{Cl}_2
\]

31. When aqueous solutions of silver nitrate and magnesium chloride are mixed, silver chloride precipitates. Calculate the mass of AgCl formed when 1.25 L of 0.0500 M MgCl₂ and 5.25 L of 0.0250 M AgNO₃ are mixed.

\[
\text{2 AgNO}_3 + \text{MgCl}_2 \rightarrow 2 \text{AgCl (s)} + \text{Mg(NO}_3)_2
\]

\[
\begin{align*}
5.25 \text{ L} & \quad 1.25 \text{ L} \\
0.0250 \text{ M} & \quad 0.0500 \text{ M} \\
0.131 \text{ mol} & \quad 0.0625 \text{ mol}
\end{align*}
\]

\[
0.0625 \text{ mol MgCl}_2 \left( \frac{2 \text{ mol AgCl}}{1 \text{ mol MgCl}_2} \right) \left( \frac{143.35 \text{ g AgCl}}{\text{mol AgCl}} \right) = 17.9 \text{ g AgCl}
\]

32. What mass of \( \text{K}_3\text{PO}_4 \) is needed to react with 555 mL of 0.250 M HCl? Useful molar masses are \( \text{K}_3\text{PO}_4 = 212.265 \text{ g/mol} \); HCl = 36.461 g/mol.

\[
3 \text{ HCl} + \text{K}_3\text{PO}_4 \rightarrow \text{H}_3\text{PO}_4 + \text{KCl}
\]

\[
(0.555 \text{ L}) \left( \frac{0.250 \text{ mol HCl}}{L \text{ HCl}} \right) \left( \frac{1 \text{ mol K}_3\text{PO}_4}{3 \text{ mol HCl}} \right) \left( \frac{212.265 \text{ g K}_3\text{PO}_4}{\text{mol K}_3\text{PO}_4} \right) = 9.82 \text{ g K}_3\text{PO}_4
\]
33. The following reaction forms 11.1 g of Ag (s):
\[ 2 \text{Ag}_2\text{O(s)} \rightarrow 4 \text{Ag(s)} + \text{O}_2(\text{g}) \]
What volume of gas forms if it is collected over water at a temperature of 25 °C and a total pressure of 0.989 atm? The vapor pressure of water at 25 °C is 0.0313 atm. Ag = 107.9 g/mol

\[
11.1 \text{g Ag} \left( \frac{1 \text{ mol Ag}}{107.9 \text{ g Ag}} \right) \left( \frac{1 \text{ mol O}_2}{4 \text{ mol Ag}} \right) = 0.0257 \text{ mol O}_2
\]

\[ P_T = P_{H_2O} + P_{O_2} \]

\[
0.989 \text{ atm} = 0.0313 \text{ atm} + P_{O_2}
\]

\[ 0.9577 = P_{O_2} \]

\[ V = \frac{nRT}{P} \]

\[
V = \frac{(0.0257)(0.08206)(298)}{0.9577} = 0.6570 \text{ L}
\]

34. Calcium oxalate, CaC_2O_4, is very insoluble in water. What mass of sodium oxalate, Na_2C_2O_4, is required to precipitate the calcium ion from 37.5 mL of 0.104 M CaCl_2 solution? The reaction is:

\[ \text{Na}_2\text{C}_2\text{O}_4 + \text{CaCl}_2 \rightarrow \text{CaC}_2\text{O}_4 + 2 \text{NaCl} \]

\[ \text{Na}_2\text{C}_2\text{O}_4 = 133.99 \text{ g/mol} \]

\[
(0.0375 \text{ L})(0.104 \frac{\text{mol CaCl}_2}{\text{L}})(\frac{1 \text{ mol Na}_2\text{C}_2\text{O}_4}{1 \text{ mol CaCl}_2})(\frac{133.99 \text{ g Na}_2\text{C}_2\text{O}_4}{\text{mol}})
\]

\[ = 0.5239 \text{ g Na}_2\text{C}_2\text{O}_4 \]

35. What volume of H_2 gas, measured at 37 °C and 0.971 atm, can be obtained by reacting 4.00 g zinc metal with 150. mL of 0.250 M HCl? The equation follows. The molar masses are: Zn = 65.38 g/mol; HCl = 36.458 g/mol; ZnCl_2 = 136.28 g/mol; H_2 = 2.016 g/mol

\[ \text{Zn(s)} + 2 \text{HCl (aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2(\text{g}) \]

\[
4.00 \text{ g Zn} \left( \frac{\text{mol Zn}}{65.38 \text{ g}} \right) \left( \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}} \right) = 0.060118 \text{ mol H}_2
\]

\[
0.150 \text{ L} \left( \frac{0.250 \text{ mol H}_2}{\text{L}} \right) \left( \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}} \right) = 0.01875 \text{ mol H}_2 \]

\[ PV = nRT \]

\[
V = nRT = \frac{(0.01875)(0.08206)(310)}{0.971} = 0.491 \text{ L}
\]
36. Balance the following equations.

\[
\text{Al}_2\text{S}_3 (s) + 6 \text{H}_2\text{O} (l) \rightarrow 3 \text{H}_2\text{S} (g) + 2 \text{Al(OH)}_3 (s)
\]

\[
3 \text{PbO} + 2 \text{NH}_3 \rightarrow 3 \text{Pb} + \text{N}_2 + 3 \text{H}_2\text{O}
\]

\[
2 \text{N}_2\text{H}_4 + \text{N}_2\text{O}_4 \rightarrow 3 \text{N}_2 + 4 \text{H}_2\text{O}
\]

\[
2 \text{C}_4\text{H}_{10} + 13 \text{O}_2 \rightarrow 8 \text{CO}_2 + 10 \text{H}_2\text{O}
\]

\[
4 \text{NO}_2(g) + 2 \text{H}_2\text{O}(l) + \text{O}_2(g) \rightarrow 4 \text{HNO}_3(\text{aq})
\]

\[
2 \text{BF}_3(g) + 3 \text{H}_2\text{O}(g) \rightarrow \text{B}_2\text{O}_3 + 6 \text{HF} (g)
\]

Extra Credit (5 points):
Ammonium carbonate decomposes upon heating according to the following balanced equation.
\[(\text{NH}_4)_2\text{CO}_3 (s) \rightarrow 2 \text{NH}_3 (g) + \text{CO}_2 (g) + \text{H}_2\text{O} (g)\]
Calculate the total volume of gas produced at 22 °C and 1.02 atm by the complete decomposition of 15.55 g of ammonium carbonate. \((\text{NH}_4)_2\text{CO}_3 = 96.094 \text{ g/mol}\)

\[15.55 \text{g} (\text{NH}_4)_2\text{CO}_3 \left( \frac{1 \text{ mol}}{96.094 \text{ g}} \right) = 0.162 \text{ mol } (\text{NH}_4)_2\text{CO}_3\]

Gives

\[
0.324 \text{ mol NH}_3 \\
0.162 \text{ mol CO}_2 \\
0.162 \text{ mol H}_2\text{O}
\]

\[
0.648 \text{ mol gas}
\]

\[
P \frac{\text{PV}}{\text{nRT}} = \frac{\text{V}}{\text{P}} \left( \frac{0.648 \times 0.08206 \times 295}{1.02 \text{ atm}} \right)
\]

\[= 15.4 \text{ L}\]
# Periodic Table of the Elements

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