PART I Multiple Choice *(45 pts.)* Choose **one** correct answer for each of the following 15 questions.

1. If 18.50 moles of $C_2Cl_4(\ell)$ are required for a chemical reaction, determine the volume, in liters, of this liquid compound that are needed. The density of $C_2Cl_4(\ell)$ is 1.63 g/mL and its MW = 165.8 g/mole.

   A. 5.00 mL
   (B.) 1.88 L
   C. 5.00 L
   D. 1.88 mL
   E. none of the above

$$18.50\,mol\,C_2Cl_4 \left| \frac{165.8\,g\,C_2Cl_4}{1\,mol\,C_2Cl_4} \right| \frac{1\,mL}{1.63\,g} \left| \frac{1\,L}{1000\,mL} \right.$$

2. An example of a **weak** electrolyte in aqueous solution is

   A. only nitric acid solution
   B. only ammonium chloride solution
   (C.) only acetic acid solution
   D. only sodium chlorate solution
   E. more than one of the above

HNO_3 is a strong acid, thus strong electrolyte
NH_4Cl is a soluble salt, thus strong electrolyte
weak acid, thus weak electrolyte
soluble salt, thus strong electrolyte

3. How many **atoms** are in 75.0 g of nitrogen gas?

   A. 1.61×10^{24} atoms
   B. 6.44×10^{24} atoms
   C. 6.32×10^{24} atoms
   (D.) 3.22×10^{24} atoms
   E. none of the above

$$75.0\,g\,N_2 \left| \frac{1\,mol\,N_2}{28\,g\,N_2} \right| \frac{2\,mol\,N}{1\,mol\,N_2} \left| \frac{6.022\times10^{23}\,atoms\,N}{1\,mol\,N} \right.$$

4. How many grams of Al metal, Al(s), are needed to produce 100.0 g of $Al_2(SO_4)_3(s)$ (FW = 342.17) from the reaction of aluminum metal with sulfuric acid?

   A. 7.90 g
   B. 316 g
   (C.) 15.8 g
   D. 31.6 g
   E. none of the above

$$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3 + 3H_2(g)$$

$$100.0\,g\,Al_2(SO_4)_3 \left| \frac{1\,mol\,Al_2(SO_4)_3}{342.17\,g\,Al_2(SO_4)_3} \right| \frac{2\,mol\,Al}{1\,mol\,Al_2(SO_4)_3} \left| \frac{26.98\,g\,Al}{1\,mol\,Al} \right.$$

5. A sample of $Mg(ClO_3)_2$ (FW = 191.2) contains 3.60×10^{23} oxygen atoms. How many grams of chlorine atoms does the sample contain?

   A. 21.2 g
   B. 19.8 g
   (C.) 7.1 g
   D. 14.1 g
   E. none of the above

$$3.60\times10^{23}\,O\,atoms \left| \frac{1\,mol\,O}{6.022\times10^{23}\,atoms\,O} \right| \frac{2\,mol\,Cl}{6\,mol\,O} \left| \frac{35.45\,g\,Cl}{1\,mol\,Cl} \right.$$

6. An oxide of lead contains 90.65% Pb and 9.35% O by weight. Determine its empirical formula.

AW of Pb = 207.2 g/mole; AW of O = 16.0 g/mole

A. PbO_2
B. Pb_2O_3
C. PbO
D. Pb_3O_4
E. none of the above

Assume 100. g of compound, then:

$$\frac{90.65\text{g Pb}}{207.2\text{g Pb}} \left|\frac{1\text{mol Pb}}{}\right. = \frac{0.4375\text{mol Pb}}{0.4375} = 1\text{mol Pb}$$

$$\frac{9.35\text{g O}}{16.00\text{g O}} \left|\frac{1\text{mol O}}{}\right. = \frac{0.584375\text{mol O}}{0.4375} = 1.33\text{mol O}$$

multiply both by 3 to get whole #s

7. How many grams of magnesium (at.no.12) contain the same number of atoms as 20.04 g of calcium (at.no.20)?

A. 24.30 g
B. 40.08 g
C. 12.15 g
D. 48.60 g
E. none of the above

$$20.04\text{g Ca} \left|\frac{1\text{mol Ca}}{40.08\text{g Ca}}\right|\frac{1\text{mol Mg}}{1\text{mol Ca}}\left|\frac{24.30\text{g Mg}}{1\text{mol Mg}}\right.$$

* note that equal # of moles contain equals #s of atoms, so no conversion needed

8. The complete combustion of propane gas, $C_3H_8(g)$ with oxygen gas produces carbon dioxide and water. How many grams of $O_2(g)$ are required to burn 150 of propane?

A. 545 g
B. 109 g
C. 1320 g
D. 273 g
E. none of the above

$$C_3H_8(g) + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$$

$$150.\text{g } C_3H_8 \left|\frac{1\text{mol } C_3H_8}{44\text{g } C_3H_8}\right|\frac{5\text{ mol } O_2}{1\text{ mol } C_3H_8}\left|\frac{32\text{g } O_2}{1\text{mol } O_2}\right.$$

9. How many mL of water should be added to 25.0 m L of a stock 12.0 M HCl(aq) solution to make 1.50 M HCl(aq)? Assume that the volumes are additive.

A. 175 mL
B. 200 mL
C. 4.50 mL
D. 275 mL
E. none of the above

$$M_1V_1 = M_2V_2$$

$$(12.0\text{M})(25.0\text{mL}) = (1.50\text{M})(x\text{ mL})$$

$$\frac{(12.0\text{M})(25.0\text{mL})}{(1.50\text{M})} = x\text{ mL}$$

$x = 200\text{mL} - 25.0\text{mL} =$

10. Element M forms an oxide, M_2O_3, that is 65.2% M and 34.8% oxygen by weight. The atomic mass (weight) of M is

A. 52.0 g/mole
B. 65.4 g/mole
C. 45.0 g/mole
D. 55.8 g/mole
E. none of the above

3 mol of O = 48 g, which is 34.8% (0.348) of the compound's mass

$$\frac{48\text{g}}{x} = 0.348 \quad x = 137.93\text{g (the molar mass of } M_2O_3)$$

$$137.93\text{g} - 48\text{g} = 89.93\text{g}$$

$$\frac{89.93\text{g}}{2\text{mol M}} = 44.95\text{ g/mol}$$

11. How many mL of a 0.200 M NaOH(aq) solution contain 2.00 g NaOH (FW = 40.0)?

$$2.00\text{ g NaOH} \left|\frac{1\text{ mol NaOH}}{40.0\text{ g NaOH}}\right|\frac{1000\text{ mL solution}}{0.200\text{ mol NaOH}}$$

A. 400 mL
B. 25.0 mL
C. 40 mL
(D.) 250 mL
E. none of the above

12. The element $_{29}Cu$, which has an average atomic mass of 63.546, consists of two isotopes: isotope A with an isotopic mass of 62.930 amu, and isotope B with an isotopic mass of 64.928 amu. The relative fractional abundance of the heavier isotope B is

avg atomic mass = (%A)(mass A) + (%B)(mass B)

%A + %B = 100 % or A + B = 1 B = 1 − A

63.546 amu = (A)(62.930 amu) + (1−A)(64.928 amu)

63.546 amu = 62.930 amu A + 64.928 amu − 64.928 amu A

1.998 amu A = 1.382 2mu A = 0.69169

B = 1 − 0.69169

A. 0.36
B. 0.69
C. 0.64
(D.) 0.31
E. none of the above

13. What weight of $KClO_3(s)$ (FW = 122.55) contains 5.0 g of oxygen atoms?

$$5.0\text{ g O} \left|\frac{1\text{ mol O}}{16.00\text{ g O}}\right|\frac{1\text{ mol } KClO_3}{3\text{ mol O}}\left|\frac{122.55\text{ g } KClO_3}{1\text{ mol } KClO_3}\right.$$

A. 1.99 g
B. 7.66 g
(C.) 12.77 g
D. 38.3 g
E. none of the above

14. Which of the following equations represents a redox reaction?

1. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
2. $CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(s)$
3. $2\,SO_2(g) + O_2(g) \rightarrow 2\,SO_3(g)$ I know this is a redox because $O_2(g)$ is in its elemental state as reactant side ($ox^{\#} = 0$) and in a compd on the product side ($ox^{\#} \neq 0$)
4. $P_4O_{10}(s) + 6\,H_2O(\ell) \rightarrow 4\,H_3PO_4(aq)$

(A.) one of the four reactions
B. two of the four reactions
C. three of the four reactions
D. four of the four reactions
E. none of the four reactions

15. If 26.32 mL of 0.10 M H_2SO_4(aq) is neutralized by 34.56 mL of NaOH(aq) solution, determine the molarity of the NaOH(aq).

$$26.32\text{ mL}\left|\frac{0.10\text{ mol } H_2SO_4}{1000\text{ mL}}\right|\frac{2\text{ mol NaOH}}{1\text{ mol } H_2SO_4}\left|\frac{}{34.56\text{ mL}}\right|\frac{1000\text{ mL}}{1\text{ L}}$$

A. 0.26 M
(B.) 0.15 M
C. 0.075 M
D. 0.13 M
E. none of the above

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(\ell)}$$

PART IIA *(14 pts.)*

1. The common name of the symbol $_{33}As$ is arsenic
2. The common name of the symbol $_{27}Co$ is cobalt
3. The name of $Mn_3(PO_4)_2$ is manganese (II) phosphate
4. The name of SiF_4 is silicon tetrafluoride
5. The formula of iron(III) sulfide is Fe_2S_3
6. The formula of aluminum nitrite is $Al(NO_2)_3$
7. The oxidation state of Cr in $(NH_4)_2Cr_2O_7$ is 6+

PART IIB *(22 pts.)*

1. *(8 pts.)*

   A. 4.0 kilograms is equivalent to 4.0×10^{12} nanograms. $\frac{4.0\,kg}{1}\left|\frac{1000\,g}{1\,kg}\right|\frac{10^9\,ng}{1\,g}$

   B. The diameter of 6.0 μm (micrometers) of a red blood cell is equivalent to 6.0×10^6 picometers. $\frac{6\,\mu m}{1}\left|\frac{1\,m}{10^6\,\mu m}\right|\frac{10^{12}\,pm}{1\,m}$

   C. The density of a 6.0 g/cm^3 is equivalent to 1.3×10^4 lb/m^3, where 1.0 pound is equivalent to 454 grams. $\frac{6.0\,g}{1\,cm^3}\left|\frac{1\,lb}{454\,g}\right|\frac{(100\,cm)^3}{(1\,m)^3}$

   D. If the mass of one atom of an element is 1.709×10^{-22} g, the identity (symbol) of the element is Rh.
   $\frac{1.709\times10^{-22}\,g}{1}\left|\frac{6.022\times10^{23}\,atoms}{1\,mole}\right. = 102.9\,g/mol$

2. *(6 pts.)* For **one** particular X^{2+} ion with pure (100%) isotopic mass of 49.9621 amu which has 20 electrons.

   A. The mass number is 50.

   B. The number of protons is 22.

   C. The number of neutrons is 28.

3. *(8 pts.)*

   A. The J.J. Thomson cathode ray experiment in 1897 determined the charge/mass ratio of an electron.

   B. The R. Millikan oil drop experiment in 1909 determined the charge of an electron.

   C. The E. Rutherford scattering experiment in 1911 involving the bombardment of gold foil with alpha $^4_2He^{2+}$ particles determined the mass + charge of the atom are concentrated in a very small area (the nucleus)

   D. Isotopes and their relative fractional abundances of an element were determined from analytical measurements with mass spectrometer.

PART IIC *(7 pts.)* For the problem below, show all of your work (including units) for credit.

1. Aluminum metal reacts with $PbO_2(s)$ to give $Al_2O_3(s)$ and Pb(s) in accordance with the following balanced equation.

$$4\ Al(s) + 3\ PbO_2(s) \rightarrow 2\ Al_2O_3(s) + 3\ Pb(s)$$

In one experiment, 200 g of Al(s) and 400 g of $PbO_2(s)$ are mixed and allowed to react by ignition to form the above products.

A. The limiting reactant (reagent) is PbO_2.

$$200.\text{g Al} \left| \frac{1\text{ mol Al}}{26.98\text{g Al}} \right| \frac{3\text{ mol Pb}}{4\text{ mol Al}} \left| \frac{207.2\text{g Pb}}{1\text{ mol Pb}} \right| = 1152\text{ g Pb}$$

$$400\text{g PbO}_2 \left| \frac{1\text{ mol PbO}_2}{239.2\text{g PbO}_2} \right| \frac{3\text{ mol Pb}}{3\text{ mol PbO}_2} \left| \frac{207.2\text{g Pb}}{1\text{ mol Pb}} \right| = 346\text{ g Pb}$$

* since the am't of PbO yields less Pb(s), PbO limits how much product can be made

B. Calculate the maximum number of atoms of solid lead, Pb(s) formed by the above reaction.

$$400\text{g PbO}_2 \left| \frac{1\text{ mol PbO}_2}{239.2\text{g PbO}_2} \right| \frac{3\text{ mol Pb}}{3\text{ mol PbO}_2} \left| \frac{6.022\times10^{23}\text{ atoms Pb}}{1\text{ mol Pb}} \right| =$$

answer 1.01×10^{24} atoms Pb

C. The reducing agent in the above redox reaction is $Al(s)$.

Aluminum goes from an oxidation state of zero (reactant side) to an oxidation state of 3^+ (product side) Thus, aluminum was oxidized, and Al(s) is the reducing agent

PART IID *(15 pts.)* Write a **balanced net** equation for each of the following. If no reaction occurs, write NO REACTION as the final answer in the space provided.

Hint: Initially write a balanced molecular equation and then the corresponding net equation.

1. *(3 pts.)* Electrolysis of liquid water to give hydrogen and oxygen gases (demo).

$$2H_2O_{(l)} \longrightarrow 2H_{2(g)} + O_{2(g)}$$

2. *(3 pts.)* Preparation of aqueous ammonium nitrate solution from acid/base reaction.

$$NH_4OH_{(aq)} + HNO_{3(aq)} \rightarrow NH_4NO_{3(aq)} + H_2O_{(l)}$$

$$NH_4OH_{(aq)} + H^+_{(aq)} + \cancel{NO_3^-_{(aq)}} \rightarrow NH_4^+_{(aq)} + \cancel{NO_3^-_{(aq)}} + H_2O_{(l)}$$

Net: $NH_4OH_{(aq)} + H^+_{(aq)} \longrightarrow NH_4^+_{(aq)} + H_2O_{(l)}$

3. *(3 pts.)* Formation of magnesium chlorate(aq) from a reaction producing carbon dioxide gas.

$$MgCO_{3(s)} + 2HClO_{4(aq)} \longrightarrow Mg(ClO_4)_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$$MgCO_{3(s)} + 2H^+_{(aq)} + \cancel{2ClO_4^-_{(aq)}} \rightarrow Mg^{2+}_{(aq)} + \cancel{2ClO_4^-_{(aq)}} + CO_{2(g)} + H_2O_{(l)}$$

NET: $MgCO_{3(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

4. *(3 pts.)* Zinc metal is added to hydrochloric acid (demo). Note that $ZnCl_2$ is soluble in $H_2O(\ell)$.

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

$$Zn_{(s)} + 2H^+_{(aq)} + \cancel{2Cl^-_{(aq)}} \rightarrow Zn^{2+}_{(aq)} + \cancel{2Cl^-_{(aq)}} + H_{2(g)}$$

NET: $Zn_{(s)} + 2H^+_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_{2(g)}$

5. *(3 pts.)* Milk of magnesia (magnesium hydroxide) is taken to reduce acidity of hydrochloric acid (demo) in stomach. Note that $MgCl_2$ is soluble in $H_2O(\ell)$.

$$Mg(OH)_{2(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

$$Mg(OH)_{2(s)} + 2H^+_{(aq)} + \cancel{2Cl^-_{(aq)}} \rightarrow Mg^{2+}_{(aq)} + \cancel{2Cl^-_{(aq)}} + 2H_2O_{(l)}$$

NET: $Mg(OH)_{2(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + 2H_2O_{(l)}$