**CHE1031 HW set 4: Stoichiometry of chemical reactions**

*Please solve these problems on green engineering graph paper.*

*Problems are assigned at each class meeting and are due at the next class.*

*Please number each problem, show all work for credit and box your answer.
Note that answers to quantitative problems are provided in blue.*

**4.1: Writing and balancing chemical equations**

**1.** What does it mean to say an equation is balanced? Why is it important for an equation to be balanced?

**2.** Consider ‘molecular’, complete ionic, and net ionic chemical equations.

(a) What is the difference between these types of equations?

(b) In what circumstance would the complete and net ionic equations for a reaction be identical?

**3.** Balance these chemical equations.

(a) PCl5(*s*) + H2O(*l*) ⟶ POCl3(*l*) + HCl(*aq*)

(b) H2(*g*) + I2(*s*) ⟶ HI(*s*)

(c) Fe(*s*) + O2(*g*) ⟶ Fe2O3(*s*)

(d) Na(*s*) + H2O(*l*) ⟶ Na(OH)(*aq*) + H2(*g*)

(e) (NH4)2(Cr2O7)(*s*) ⟶ Cr2O3(*s*) + N2(*g*) + H2O(*g*)

(f) P4(*s*) + Cl2(*g*) ⟶ PCl3(*l*)

(g) PtCl4(*s*) ⟶ Pt(*s*) + Cl2(*g*)

**4.** Write a balanced chemical equation describing each of the following chemical reactions.

(a) Solid calcium carbonate is heated and decomposes to solid calcium oxide and carbon dioxide gas.

(b) Gaseous butane, C4H10, reacts with diatomic oxygen gas to yield gaseous carbon dioxide and water vapor.

(c) Aqueous solutions of magnesium chloride and sodium hydroxide react to produce solid magnesium hydroxide and aqueous sodium chloride.

(d) Water vapor reacts with sodium metal to produce solid sodium hydroxide and hydrogen gas.

**5.** From each of these balanced chemical equations, write:

(i) the complete ionic; and

(ii) the net ionic equations.

(a) K2(C2O4)(aq) + Ba(OH)2(aq) ⟶ 2K(OH)(aq) + Ba(C2O4)(s)

(b) Pb(NO3)2(aq) + H2(SO4)(aq) ⟶ Pb(SO4)(s) + 2H(NO3)(aq)

(c) Ca(CO3)(s) + H2(SO4)(aq) ⟶ Ca(SO4)(s) + CO2(g) + H2O(l)

**4.2: Classifying chemical reactions**

**6.** Indicate what type, or types, of reaction each of these balanced equations represents.

(a) H2O(g) + C(s) ⟶ CO(g) + H2(g)

(b) 2K(ClO3)(s) ⟶ 2KCl(s) + 3O2(g)

(c) Al(OH)3(aq) + 3HCl(aq) ⟶ AlCl3(aq) + 3H2O(l)

(d) Pb(NO3)2(aq) + H2(SO4)(aq) ⟶ Pb(SO4)(s) + 2H(NO3)(aq)

**7.** Determine the oxidation numbers of the elements in the compounds listed.
(None of the oxygen-containing compounds are peroxides or superoxides.)

(a) H3(PO4)

(b) Al(OH)3

(c) SeO2

**8.** Classify the following as acid-base reactions or oxidation-reduction reactions.
 *Try assigning oxidation numbers.*

(a) Na2S(aq) + 2HCl(aq) ⟶ 2NaCl(aq) + H2S(g)

(b) 2Na(s) + 2HCl(aq) ⟶ 2NaCl(aq) + H2(g)

(c) Mg(s) + Cl2(g) ⟶ MgCl2(s)

**9.** Complete and balance these acid-base equations.

(a) A solution of H(ClO4) is added to a solution of Li(OH).

(b) Aqueous H2SO4 reacts with Na(OH).

(c) Ba(OH)2 reacts with HF gas.

**10.** Write the complete, total ionic, and net ionic equations for the following reactions:

(a) Ca(OH)2(aq) + H(C2H3O2)(aq) ⟶

(b) H3(PO4)(aq) + CaCl2(aq) ⟶

**11.** Write balanced chemical equations for the reactions used to prepare each of the following compounds from the given starting material(s). In some cases, additional reactants may be required.

(a) solid ammonium nitrate from gaseous molecular nitrogen via a two-step process (first reduce the nitrogen to ammonia, then neutralize the ammonia with an appropriate acid)

(b) gaseous hydrogen bromide from liquid molecular bromine via a one-step redox reaction

(c) gaseous H2S from solid Zn and S via a two-step process (first a redox reaction between the starting materials, then reaction of the product with a strong acid)

**12.** Complete and balance each of the following half-reactions (steps 2–5 in half-reaction method):

(a) Sn+4(aq) ⟶ Sn+2(aq)

(b) Ag(NH3)+2(aq) ⟶ Ag(s) + NH3(aq)

(c) Hg2Cl2(s) ⟶ Hg(l) + Cl−1(aq)

(d) H2O(l) ⟶ O2(g) (in acidic solution)

(e) IO3−1(aq) ⟶ I2(s)

(f) SO3-2(aq) ⟶ SO4-2(aq) (in acidic solution)

(g) MnO4-1(aq) ⟶ Mn+2(aq) (in acidic solution)

**13.** Balance the following equation according to the half-reaction method:

Br2(*l*) + SO2(*g*) ⟶ Br−1(*aq*) + SO4-2(*aq*) (in acid)

**4.3: Reaction stoichiometry**

**14.** Write the balanced equation, then determine the information requested in each of the following:

(a) The number of moles and the mass of chlorine, Cl2, required to react with 10.0 g of sodium metal, Na, to produce sodium chloride, NaCl.
*0.217 mol Cl2; 15.4 g Cl2*

(b) The number of moles and the mass of oxygen formed by the decomposition of 1.252 g of mercury (II) oxide.

 *2.890 E-3 mol O2; 0.09243 g O2*

(c) The number of moles and the mass of sodium nitrate, Na(NO3), required to produce 128 g of oxygen. (Na(NO2) is the other product.)
*8.01 mol Na(NO3); 680.6 g Na(NO3)*

**15.** H2 is produced by the reaction of 118.5 mL of a 0.8775-M solution of H3(PO4) according to the following equation: 2Cr + 2H3(PO4) ⟶ 3H2 + 2Cr(PO4).

Determine the number of moles and mass of H2.

 *0.1560 mol H2; 0.3151 g H2*

**16.** I2 is produced by the reaction of 0.4235 mol of CuCl2 according to the following equation:

2CuCl2 + 4KI ⟶ 2CuI + 4KCl + I2.

(a) How many molecules of I2 are produced? *1.275 E23 molecules I2*

(b) What mass of I2 is produced? *53.74 g I2*

**17.** Urea, CO(NH2)2, is manufactured on a large scale for use in producing urea-formaldehyde plastics and as a fertilizer. What is the maximum mass of urea that can be manufactured from the CO2 produced by combustion of 1.00 E3 kg of carbon followed by the reaction?

CO2(g) + 2NH3(g) ⟶ CO(NH2)2(s) + H2O(l)

*8.33 E4 mol CO2; 5.00 E6 g CO(NH4)2*

**18.** What volume of 0.750 M hydrochloric acid solution can be prepared from the HCl produced by the reaction of 25.0 g of NaCl with excess sulfuric acid?

NaCl(s) + H2(SO4)(l) ⟶ HCl(g) + Na(HSO4)(s)

*0.570 L of HCl*

**19.** What volume of a 0.2089 M KI solution contains enough KI to react exactly with the Cu(NO3)2 in 43.88 mL of a 0.3842 M solution of Cu(NO3)2?

2Cu(NO3)2 + 4KI ⟶ 2CuI + I2 + 4K(NO3)

*0.1614 L*

**4.4: Reaction yields**

**20.** The following quantities are placed in a container: 1.5 E24 atoms of hydrogen, 1.0 mol of sulfur, and 88.0 g of diatomic oxygen.

(a) What is the total mass in grams for the collection of all three elements?

(b) What is the total number of moles of atoms for the three elements?

(c) If the mixture of the three elements formed a compound with molecules that contain two hydrogen atoms, one sulfur atom, and four oxygen atoms, which substance is consumed first?

(d) How many atoms of each remaining element would remain unreacted in the change described in (c)?

*(a) 1.2 E2 g*

*(b) 9.0 mol*

*(c) S limits*

*(d) left: 3.01 E23 mol H; 9.0 E23 atoms O*

**21.** What is the limiting reactant in a reaction that produces sodium chloride from 8 g of sodium and 8 g of diatomic chlorine?

*Cl2 limits*

**22.** A sample of 0.53 g of carbon dioxide was obtained by heating 1.31 g of calcium carbonate. What is the percent yield for this reaction?

Ca(CO3)(s) ⟶ CaO(s) + CO2(s)

*92.0%*

**23.** Citric acid, C6H8O7, a component of jams, jellies, and fruity soft drinks, is prepared industrially via fermentation of sucrose by the mold Aspergillus niger. The equation representing this reaction is:

C12H22O11 + H2O + 3O2 ⟶ 2C6H8O7 + 4H2O

What mass of citric acid is produced from exactly 1 metric ton (1.000 E3 kg) of sucrose if the yield is 92.30%?

*1.036 E6 g or 1.036 E3 kg*

**24.** How many molecules of the sweetener saccharin (C7H5NO3S) can be prepared from 30 C atoms, 25 H atoms, 12 O atoms, 8 S atoms, and 14 N atoms?
*O limits the yield of 4 molecules*



**25.** The phosphorus pentoxide used to produce phosphoric acid for cola soft drinks is prepared by burning phosphorus in oxygen.

(a) What is the limiting reactant when 0.200 mol of P4 and 0.200 mol of O2 react according to: P4 + 5O2 ⟶ P4O10

(b) Calculate the percent yield if 10.0 g of P4O10 is isolated from the reaction.

 *(a) O2 limits*

 *(b) 87.7%*

**4.5: Quantitative chemical analysis**

**26.** In a common medical laboratory determination of the concentration of free chloride ion in blood serum, a serum sample is titrated with a Hg(NO3)2 solution.

2Cl−1(aq) + Hg(NO3)2(aq) ⟶ 2NO3−1(aq) + HgCl2(s)

What is the Cl−1 concentration in a 0.25-mL sample of normal serum that requires 1.46 mL of 8.25 × 10−4 M Hg(NO3)2(aq) to reach the end point?

*9.64 E-3 M*

**27.** The principal component of mothballs is naphthalene, a compound with a molecular mass of about 130 amu, containing only carbon and hydrogen. A 3.000-mg sample of naphthalene burns to give 10.3 mg of CO2. Determine its empirical and molecular formulas.

*C10H8 or C10H9*

**28.** What volume of 0.08892 M H(NO3) is required to react completely with 0.2352 g of potassium hydrogen phosphate?

2H(NO3)(aq) + K2(HPO4)(aq) ⟶ H3(PO4)(aq) + 2K(NO3)(aq)

*0.03035 L*

**29.** What volume of a 0.3300-M solution of sodium hydroxide would be required to titrate 15.00 mL of 0.1500 M oxalic acid?

(C2O4)H2(aq) + 2Na(OH)(aq) ⟶ Na2(C2O4)(aq) + 2H2O(l)

*0.01364 L*

**30.** Potassium acid phthalate, K(HC6H4O4), or KHP, is used in many laboratories, including general chemistry laboratories, to standardize solutions of base. KHP is one of only a few stable solid acids that can be dried by warming and weighed. A 0.3420-g sample of K(HC6H4O4) reacts with 35.73 mL of a Na(OH) solution in a titration.

What is the molar concentration of the Na(OH)?

 K(HC6H4O4)(aq) + Na(OH)(aq) ⟶ KNa(C6H4O4)(aq) + H2O(aq)

*0.05313 M*