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

*These are optional practice problems. It’s up to you how to solve them and they don’t need to be completed or passed in. As the answer key is posted with this problem set, you may find them useful in ‘reverse engineering’ HW problems or in studying for quizzes and exams.*

*Note that answers to quantitative problems are provided in blue.*

**4.1: Writing and balancing chemical equations**

**1.** Balance the following equations:

(a) P4(*s*) + O2(*g*) ⟶ P4O10(*s*)

(b) Pb(*s*) + H2O(*l*) + O2(*g*) ⟶ Pb(OH)2(*s*)

(c) Sc2O3(*s*) + SO3(*l*) ⟶ Sc2(SO4)3(*s*)

(d) Ca3(PO4)2(*aq*) + H3(PO4)(*aq*) ⟶ Ca(H2PO4)2(*aq*)

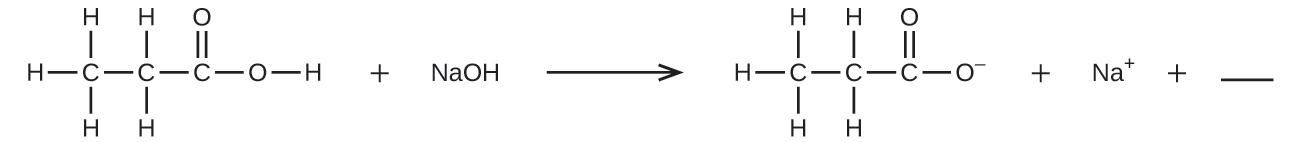
(e) Al(*s*) + H2(SO4)(*aq*) ⟶ Al2(SO4)3(*s*) + H2(*g*)

(f) TiCl4(*s*) + H2 O(*g*) ⟶ TiO2(*s*) + HCl(*g*)

**2.** This chemical reaction is missing a product.

(a) Fill in the blank with a single chemical formula for a covalent compound that balances the equation.

(b) Re-write the equation using chemical formulas for reactants and products.

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**3.** Aqueous hydrogen fluoride (hydrofluoric acid) is used to etch glass and to analyze minerals for their silicon content. Hydrogen fluoride will also react with sand (silicon dioxide).

Write an equation for the reaction of solid silicon dioxide with hydrofluoric acid to yield gaseous silicon tetrafluoride and liquid water.

**4.2: Classifying chemical reactions**

**4.** Complete and balance this acid-base reaction: a solution of Sr(OH)2 is added to a solution of H(NO3).

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

(a) H2(SO4)

(b) Ca(OH)2

(c) Br(OH)

(d) Cl(NO2)

(e) TiCl4

(f) NaH

**6.** Identify the atoms that are oxidized and reduced, the change in oxidation state for each, and the oxidizing and reducing agents in each of the following equations:

(a) Mg(s) + NiCl2(aq) ⟶ MgCl2(aq) + Ni(s)

(b) PCl3(l) + Cl2(g) ⟶ PCl5(s)

(c) C2H4(g) + 3O2(g) ⟶ 2CO2(g) + 2H2O(g)

(d) Zn(s) + H2(SO4)(aq) ⟶ Zn(SO4)(aq) + H2(g)

(e) 2K2S2O3(s) + I2(s) ⟶ K2S4 O6(s) + 2KI(s)

(f) 3Cu(s) + 8H(NO3)(aq) ⟶ 3Cu(NO3)2(aq) + 2NO(g) + 4H2 O(l)

**7.** Complete and balance the following oxidation-reduction reactions, which give the highest possible oxidation state for the oxidized atoms.

(a) Al(s) + F2(g) ⟶

(b) Al(s) + CuBr2(aq) ⟶ (single displacement)

(c) P4(s) + O2(g) ⟶

(d) Ca(s) + H2O(l) ⟶ (products are a strong base and a diatomic gas)

**8.** Complete and balance the equations for the following acid-base neutralization reactions. If water is used as a solvent, write the reactants and products as aqueous ions. In some cases, there may be more than one correct answer, depending on the amounts of reactants used.

(a) Mg(OH)2(s) + H(ClO4)(aq) ⟶

(b) SO3(g) + H2O(l) ⟶ (assume an excess of water and that the product dissolves)

(c) SrO(s) + H2(SO4)(l) ⟶

**9.** Silver can be separated from gold because silver dissolves in nitric acid while gold does not. Is the dissolution of silver in nitric acid an acid-base reaction or an oxidation-reduction reaction? Explain your answer.

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

(a) K(NO2)

(b) In2S3

(c) P4O6

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

(a) MgO(s) + 2HCl(aq) ⟶ MgCl2(aq) + H2O(l)

(b) K3P(s) + 2O2(g) ⟶ K3(PO4)(s)

(c) 3K(OH)(aq) + H3(PO4)(aq) ⟶ K3(PO4)(aq) + 3H2O(l)

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

(a) Hg(l) + Br−1(aq) ⟶ HgBr4-2(aq)

(b) ZnS(s) ⟶ Zn(s) + S-2(aq)

(c) H2(g) ⟶ H3O+1(aq) (in acidic solution)

(d) Cl−1(aq) ⟶ ClO3−1(aq) (in acidic solution)

**13.** Complete and balance each of these half-reactions:

(a) Cr+2(aq) ⟶ Cr+3(aq)

(b) NO3−1(aq) ⟶ HNO2(aq) (in acidic solution)

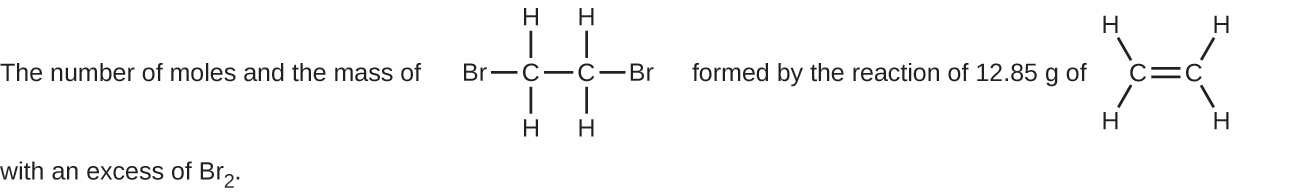
**14.** In a common experiment in the general chemistry laboratory, magnesium metal is heated in air to produce MgO. MgO is a white solid, but in these experiments it often looks gray, due to small amounts of Mg3N2, a compound formed as some of the magnesium reacts with nitrogen. Write a balanced equation for each reaction.

**4.3: Reaction stoichiometry**

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

(a) The number of moles and the mass of carbon dioxide formed by the combustion of 20.0 kg of carbon in an excess of oxygen.

(b) The number of moles and the mass of copper (II) carbonate needed to produce 1.500 kg of copper (II) oxide. (CO2 is the other product.)

(c)

**16.** Carborundum is silicon carbide, SiC, a very hard material used as an abrasive on sandpaper and in other applications. It is prepared by the reaction of pure sand, SiO2, with carbon at high temperature. Carbon monoxide, CO, is the other product of this reaction. Write the balanced equation for the reaction, and calculate how much SiO2 is required to produce 3.00 kg of SiC.

**17.** Automotive air bags inflate when a sample of sodium azide, NaN3, is very rapidly decomposed.

2NaN3(s) ⟶ 2Na(s) + 3N2(g)

What mass of sodium azide is required to produce 2.6 ft3 (73.6 L) of nitrogen gas with a density of 1.25 g/L?

**18.** In an accident, a solution containing 2.5 kg of nitric acid was spilled. Two kilograms of Na2(CO3) was quickly spread on the area and CO2 was released by the reaction. Was sufficient Na2(CO3) used to neutralize all of the acid?

**4.4: Reaction yields**

**19.** What is the limiting reactant when 1.50 g of lithium and 1.50 g of nitrogen combine to form lithium nitride, a component of advanced batteries, according to the following unbalanced equation?

Li + N2 ⟶ Li3N

**20.** How many molecules of C2H4Cl2 can be prepared from 15 C2H4 molecules and 8 Cl2 molecules?

**21.** Freon-12, CCl2F2, is prepared from CCl4 by reaction with HF. The other product of this reaction is HCl. Outline the steps needed to determine the percent yield of a reaction that produces 12.5 g of CCl2F2 from 32.9 g of CCl4. Freon-12 has been banned and is no longer used as a refrigerant because it catalyzes the decomposition of ozone and has a very long lifetime in the atmosphere. Determine the percent yield.

**22.** Toluene, C6H5CH3, is oxidized by air under carefully controlled conditions to benzoic acid, C6H5CO2H, which is used to prepare the food preservative sodium benzoate, C6H5CO2Na. What is the percent yield of a reaction that converts 1.000 kg of toluene to 1.21 kg of benzoic acid?

2C6H5CH3 + 3O2 ⟶ 2C6H5CO2H + 2H2O

**4.5: Quantitative chemical analysis**

**23.** What volume of 0.0105-M HBr solution is required to titrate 125 mL of a 0.0100-M Ca(OH)2 solution?

Ca(OH)2(aq) + 2HBr(aq) ⟶ CaBr2(aq) + 2H2O(l)

**24.** What is the concentration of NaCl in a solution if titration of 15.00 mL of the solution with 0.2503 M Ag(NO3) requires 20.22 mL of the Ag(NO3) solution to reach the end point?

Ag(NO3)(aq) + NaCl(aq) ⟶ AgCl(s) + Na(NO3)(aq)

**25.** A 0.025-g sample of a compound composed of boron and hydrogen, with a molecular mass of ~28 amu, burns spontaneously when exposed to air, producing 0.063 g of B2O3. What are the empirical and molecular formulas of the compound?

**26.** The reaction of WCl6 with Al at ~400 °C gives black crystals of a compound containing only tungsten and chlorine. A sample of this compound, when reduced with hydrogen, gives 0.2232 g of tungsten metal and hydrogen chloride, which is absorbed in water. Titration of the hydrochloric acid thus produced requires 46.2 mL of 0.1051 M Na(OH) to reach the end point. What is the empirical formula of the black tungsten chloride?