Chemical Calculations -Tutorial 5- 2025

1. Because the bond between fluorine atoms in F_2 is relatively weak while the bonds between fluorine atoms and atoms of other elements are relatively strong, it is difficult to make diatomic fluorine, F_2. One way it can be made is to run an electric current through liquid hydrogen fluoride, HF. This reaction yields hydrogen gas, H_2, and fluorine gas, F_2.

   a) Write a complete balanced equation, including states, for this reaction.
   b) Write a stoichiometry that could be used to convert between moles of HF and moles of F_2.
   c) How many moles of F_2 form when one mole of HF reacts completely?
   d) How many moles of HF react to yield 3.452 moles of H_2? (2:1, 0.5 mol, 6.904 mol)

2. Fluorine gas is an important chemical because it is used to add fluorine atoms to many different compounds. It is difficult to make, but the following two-step process produces high yields of F_2.

$$2KMnO_4 + 2KF + 10HF + 3H_2O_2 \rightarrow 2K_2MnF_6 + 8H_2O + 3O_2$$

$$2K_2MnF_6 + 4SbF_5 \rightarrow 4KSbF_6 + 2MnF_3 + F_2$$

For the second of these two reactions:

   a) Write a stoichiometry that could be used to convert between moles of antimony pentafluoride, SbF_5, and moles of fluorine, F_2.
   b) How many moles of F_2 form when 8 moles of SbF_5 react completely?
   c) What is the maximum number of moles of F_2 that could form in the combination of 2.00 moles of K_2MnF_6 and 5.00 moles of SbF_5?

(4:1, 2 mol, 1 mol)

3. The thiocyanate polyatomic ion, SCN^-, is commonly called a pseudohalogen because it acts very much like halide ions. For example, we know that the pure halogens consist of diatomic molecules, such as Cl_2. Thiocyanate ions form similar molecules in the following reaction:

$$2NaSCN + 2H_2SO_4 + MnO_2 \rightarrow (SCN)_2 + 2H_2O + MnSO_4 + Na_2SO_4$$

   a) Write a stoichiometry that could be used to convert between moles of NaSCN and moles of $(SCN)_2$.
   b) How many moles of $(SCN)_2$ form when 0.50 moles of NaSCN react completely?
   c) What is the maximum number of moles of $(SCN)_2$ that could form in the combination of 4 moles of NaSCN and 3 moles of MnO_2 if there is excess H_2SO_4?
   d) Write a stoichiometry that could be used to convert between moles of sulfuric acid, H_2SO_4, and moles of manganese(II) sulfate, $MnSO_4$.

e) What is the minimum number of moles of H_2SO_4 that must react to form 1.75 moles of manganese(II) sulfate?

(2:1, 0.25 mol, 2 mol, 2:1, 3.50 mol)

4. The tanning agent, $Cr(OH)SO_4$, is formed in the reaction of sodium dichromate ($Na_2Cr_2O_7$), sulfur dioxide, and water. Tanning protects animal hides from bacterial attack, reduces swelling, and prevents the fibers from sticking together when the hides dry. This leads to a softer, more flexible leather.

$$Na_2Cr_2O_7 + 3SO_2 + H_2O \rightarrow 2Cr(OH)SO_4 + Na_2SO_4$$

   a) How many kilograms of sodium dichromate, $Na_2Cr_2O_7$, are necessary to produce 2.50 kg of $Cr(OH)SO_4$?
   b) How many grams of sodium sulfate are formed with 250 g of $Cr(OH)SO_4$? (1.984 kg, 107.57 g)

5. The mineral hausmannite, Mn_3O_4, which contains both manganese(II) and manganese(III) ions, is formed from heating manganese(IV) oxide to 890 °C.

$$3MnO_2(l) \xrightarrow{800°C} Mn_3O_4(s) + O_2(g)$$

   a) What is the maximum mass, in kilograms, of Mn_3O_4 that can be formed from the decomposition of 31.5 kg of manganese(IV) oxide, MnO_2?
   b) If 24.5 kg of Mn_3O_4 is isolated in the decomposition reaction of 31.5 kg of manganese(IV) oxide, MnO_2, what is the percent yield? (27.635 kg, 88.67 %)

6. The equation for one process for making aluminum fluoride follows. What is the maximum mass, in grams, of aluminum fluoride, AlF_3, that can be produced from the complete reaction of 1.4×10^3 g of aluminum hydroxide, $Al(OH)_3$, with 1.0×10^3 g of H_2SiF_6? (1165.9 g)

$$2Al(OH)_3 + H_2SiF_6 \xrightarrow{100\ °C} 2AlF_3 + SiO_2 + 4H_2O$$

7. Most of the sodium chlorate, $NaClO_3$, produced in the Sri Lanka is converted into chlorine dioxide, which is then used for bleaching wood pulp.

$$NaClO_3(aq) + 2HCl(aq) \rightarrow ClO_2(g) + \frac{1}{2}Cl_2(g) + NaCl(aq) + H_2O(l)$$

   a) How many milliliters of 12.1 mol dm^{-3} HCl are necessary to react completely with 35.09 g of sodium chlorate, $NaClO_3$?
   b) What is the maximum mass, in grams, of ClO_2 that can be formed from the complete reaction of 65 mL of 12.1 mol dm^{-3} HCl?

(54.38 mL, 26.325 g)

8. When a water solution of sodium sulfite, Na_2SO_3, is added to a water solution of iron(II) chloride, $FeCl_2$, iron(II) sulfite, $FeSO_3$, precipitates from the solution.

   a) Write a balanced equation for this reaction.
   b) What is the maximum mass of iron(II) sulfite that will precipitate from a solution prepared by adding an excess of a Na_2SO_3 solution to 25.00 mL of 1.1 mol dm^{-3} $FeCl_2$?

   (3.74 g)

9. Consider the precipitation reaction that takes place when a water solution of aluminum nitrate, $Al(NO_3)_3$, is added to a water solution of potassium phosphate, K_3PO_4.
   a) Write a balanced equation for this reaction.
   b) What is the maximum mass of aluminum phosphate that will precipitate from a solution prepared by adding an excess of an $Al(NO_3)_3$ solution to 50.00 mL of 1.525 mol dm^{-3} K_3PO_4? (9.3 g)

10. Consider the neutralization reaction that takes place when nitric acid reacts with aqueous potassium hydroxide.
    a) Write a stoichiometry that relates moles of HNO_3 to moles of KOH for this reaction.
    b) What is the minimum volume of 1.50 mol dm^{-3} HNO_3 necessary to neutralize completely the hydroxide in 125.0 mL of 0.5 mol dm^{-3} KOH?

    (41.67 mL)

11. Consider the neutralization reaction that takes place when phosphoric acid reacts with aqueous potassium hydroxide.

    a) What is the minimum volume of 2.1 mol dm^{-3} H_3PO_4 necessary to neutralize completely the hydroxide in 183 mL of 0.550 mol dm^{-3} KOH? (15. 98 mL)

12. Hydriodic acid is produced industrially by the reaction of hydrazine, N_2H_4, with iodine, I_2. HI(aq) is used to make iodine salts such as AgI, which are used to seed clouds to promote rain. What is the minimum mass of iodine, I_2, necessary to react completely with 87.0 g of hydrazine, N_2H_4? (1381.8 g)

$$N_2H_4+2I_2 \rightarrow 4HI+N_2$$

13. Thionyl chloride, $SOCl_2$, is a widely used source of chlorine in the formation of pesticides, pharmaceuticals, dyes, and pigments. It can be formed from disulfur dichloride in the following reaction.

$$2SO_2 + S_2Cl_2 + 3Cl_2 \rightarrow 4SOCl_2$$

If 1.15 kg of thionyl chloride is isolated from the reaction of 457.6 grams of disulfur dichloride, S_2Cl_2, with excess sulfur dioxide and chlorine gas, what is the percent yield?(71.29 %)

14. A precipitation reaction takes place when an aqueous solution of sodium carbonate, Na_2CO_3, is added to an aqueous solution of chromium(III) nitrate, $Cr(NO_3)_3$.

    a) Write a balanced equation for this reaction.
    b) What is the maximum mass of chromium(III) carbonate that will precipitate from a solution prepared by adding an excess of a Na_2CO_3 solution to 10.00 mL of 0.100 mol dm^{-3} $Cr(NO_3)_3$?

    (0.142 g)

15. A solution is made by adding 22.6 g of a solid that is 96 % NaOH to a beaker of water. What volume of 2.00 mol dm^{-3} H_2SO_4 is necessary to neutralize the NaOH in this solution? (135 mL)

16. Sodium tripolyphosphate (or STPP), $Na_5P_3O_{10}$, is used in detergents. It is made by combining phosphoric acid with sodium carbonate at 300 to 500 °C. What is the minimum mass, in kilograms, of sodium carbonate that would be necessary to react with excess phosphoric acid to make enough STPP to produce 1×10^5 kg of a detergent that is 32% $Na_5P_3O_{10}$? (23.04×10^3 kg)

$$6H_3PO_4 + 5Na_2CO_3 \rightarrow 2Na_5P_3O_{10} + 9H_2O + 5CO_2$$

17. Hydrazine, N_2H_4, is a liquid with many industrial purposes, including the synthesis of herbicides and pharmaceuticals. It is made from urea in the following reaction at 100 °C.

$$NH_2CONH_2 + NaOCl + 2NaOH \rightarrow N_2H_4 + NaCl + Na_2CO_3 + H_2O$$

    If the percent yield for the reaction is 90%, how many kilograms of hydrazine, N_2H_4, are formed from the reaction of 243.6 kg of urea, NH_2CONH_2, with excess sodium hypochlorite and sodium hydroxide? (116.93 kg)

18. What is the molarity of a solution of sodium hydroxide, NaOH, if 36.9 mL of this solution is required to react with 35.2 mL of 0.1 mol dm^{-3} hydrochloric acid solution?

    (0.095 mol dm^{-3})

19. An impure sample of $(COOH)_2.2H_2O$ that had a mass of 2.00 g was dissolved in water and reacted with standard NaOH solution. The complete reaction required 38.32 mL of 0.198 mol dm^{-3} NaOH solution. Calculate the percent $(COOH)_2.2H_2O$ in the sample. Assume that the sample contains no acidic impurities.

    (23.87 %)