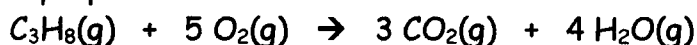


## Stoichiometry Review

1. The combustion of propane occurs via the reaction:



How many grams of oxygen are required to burn completely 10.0 g of propane?

$$\left( \frac{10.0 \text{ g C}_3\text{H}_8}{44.09652 \text{ g/mol}} \right) \left( \frac{5 \text{ mol O}_2}{1 \text{ mol C}_3\text{H}_8} \right) \left( 31.9988 \text{ g/mol} \right) = 36.3 \text{ g O}_2$$

2. Small quantities of chlorine can be prepared in the laboratory by the reaction:



What volume of chlorine at STP can be prepared from 100.0 g of manganese dioxide?

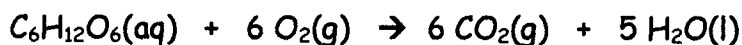
$$\left( \frac{100.0 \text{ g MnO}_2}{86.9368 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Cl}_2}{1 \text{ mol MnO}_2} \right) \left( 22.4 \text{ L/mol} \right) = 25.8 \text{ L Cl}_2$$

3. The most common ore of arsenic is mispickel, FeSAs. Upon heating this ore, free arsenic is obtained. How many grams of FeSAs are required to produce 10.0 g of arsenic according to the following reaction?



$$\left( \frac{10.0 \text{ g As}}{74.9216 \text{ g/mol}} \right) \left( \frac{1 \text{ mol FeSAs}}{1 \text{ mol As}} \right) \left( 162.8346 \text{ g/mol} \right) = 21.7 \text{ g FeSAs}$$

4. Glucose is used as an energy source by the human body. The overall reaction in the body is:



Calculate the volume of oxygen at STP required to convert 28.0 g of glucose to carbon dioxide and water.

$$\left( \frac{28.0 \text{ g C}_6\text{H}_{12}\text{O}_6}{180.15768 \text{ g/mol}} \right) \left( \frac{6 \text{ mol O}_2}{1 \text{ mol C}_6\text{H}_{12}\text{O}_6} \right) \left( 22.4 \text{ L/mol} \right) = 20.9 \text{ L O}_2$$

5. Potassium nitrate is widely used as a fertilizer because it provides two essential elements, potassium and nitrogen. It is made by mixing potassium chloride and nitric acid in the presence of oxygen according to the equation



How many kilograms of potassium nitrate will be produced from 50.0 kg of potassium chloride and 50.0 kg of nitric acid with excess oxygen?

$$\left( \frac{50\,000 \text{ g KCl}}{74.5513 \text{ g/mol}} \right) \left( \frac{4 \text{ mol KNO}_3}{4 \text{ mol KCl}} \right) \left( 101.1032 \text{ g/mol} \right) = 67\,800 \text{ g}$$

$$\left( \frac{50\,000 \text{ g HNO}_3}{63.01284 \text{ g/mol}} \right) \left( \frac{4 \text{ mol KNO}_3}{4 \text{ mol HNO}_3} \right) \left( 101.1032 \text{ g/mol} \right) = 80\,200 \text{ g}$$

$\therefore$  67.8 kg  $\text{KNO}_3$  produced

6. Bromine can be prepared by adding chlorine to an aqueous solution of sodium bromide. How many grams of bromine are formed if 25.0 g of chlorine and 25.0 g of sodium bromide are reacted according to the reaction below? Which reactant is in excess and how much remains after the reaction is complete?



$$\left( \frac{25.0 \text{ g Cl}_2}{70.906 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Br}_2}{1 \text{ mol Cl}_2} \right) (159.808 \text{ g/mol}) = 56.3 \text{ g Br}_2$$

$$\left( \frac{25.0 \text{ g NaBr}}{102.89377 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Br}_2}{2 \text{ mol NaBr}} \right) (159.808 \text{ g/mol}) = 19.4 \text{ g Br}_2$$

$\therefore$  19.4 g Br<sub>2</sub> is produced

Cl<sub>2</sub> is in excess

$$\left( \frac{25.0 \text{ g NaBr}}{102.89377 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Cl}_2}{2 \text{ mol NaBr}} \right) (70.906 \text{ g/mol}) = 8.61 \text{ g Cl}_2 \text{ required}$$

$$25.0 \text{ g} - 8.61 \text{ g} = \underline{16.4 \text{ g Cl}_2 \text{ in excess}}$$

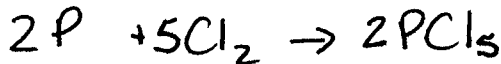
7. How many millilitres of 2.00 M hydrochloric acid are required to react with 2.55 g of zinc according to the following reaction:



$$\left( \frac{2.55 \text{ g Zn}}{65.38 \text{ g/mol}} \right) \left( \frac{2 \text{ mol HCl}}{1 \text{ mol Zn}} \right) = 0.0780 \text{ mol HCl}$$

$$V = \frac{n}{C} = \frac{0.0780 \text{ mol}}{2.00 \text{ mol/L}} = \underline{0.0390 \text{ L or } 39.0 \text{ mL}}$$

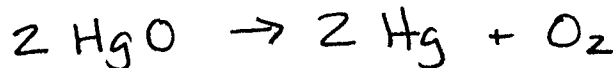
8. A 0.473 g sample of phosphorus is reacted with an excess of chlorine. Calculate the mass of phosphorus pentachloride produced.



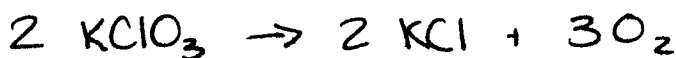
$$\left( \frac{0.473 \text{ g P}}{30.97376 \text{ g/mol}} \right) \left( \frac{2 \text{ mol PCl}_5}{2 \text{ mol P}} \right) (208.23876 \text{ g/mol}) = \underline{3.18 \text{ g PCl}_5}$$

9. How many grams of oxygen can be prepared by the decomposition of 25.0 g of mercury(II) oxide?

$$\left( \frac{25.0 \text{ g HgO}}{216.5894 \text{ g/mol}} \right) \left( \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} \right) (31.9988 \text{ g/mol}) = \underline{1.84 \text{ g O}_2}$$

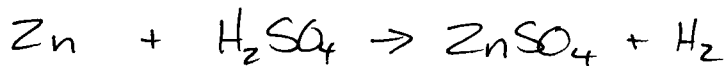


10. What volume of oxygen gas at STP can be prepared by the decomposition of 25.0 g of potassium chlorate?



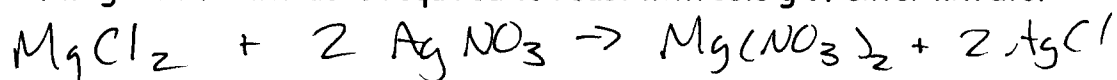
$$\left( \frac{25.0 \text{ g KClO}_3}{122.5495 \text{ g/mol}} \right) \left( \frac{3 \text{ mol O}_2}{2 \text{ mol KClO}_3} \right) (22.4 \text{ L/mol}) = \underline{6.85 \text{ L O}_2}$$

11. How many grams of zinc are required for the replacement of 0.100 g of hydrogen from sulfuric acid?



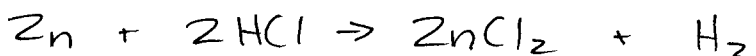
$$\left( \frac{0.100 \text{ g H}_2}{2.01528 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Zn}}{1 \text{ mol H}_2} \right) (65.38 \text{ g/mol}) = \underline{3.24 \text{ g Zn}}$$

12. What mass of magnesium chloride is required to react with 10.0 g of silver nitrate?



$$\left( \frac{10.0 \text{ g AgNO}_3}{169.8731 \text{ g/mol}} \right) \left( \frac{1 \text{ mol MgCl}_2}{2 \text{ mol AgNO}_3} \right) (95.211 \text{ g/mol}) = \underline{2.80 \text{ g MgCl}_2}$$

13. Determine the volume of hydrogen gas at STP that can be produced by the reaction of 130.0 g of zinc with 100.0 g of hydrochloric acid. Which reactant is in excess, and how much remains unreacted?



$$\left( \frac{130.0 \text{ g Zn}}{65.38 \text{ g/mol}} \right) \left( \frac{1 \text{ mol H}_2}{1 \text{ mol Zn}} \right) \left( 22.4 \text{ L/mol} \right) = 44.5 \text{ L H}_2$$

$$\left( \frac{100.0 \text{ g HCl}}{36.46094 \text{ g/mol}} \right) \left( \frac{1 \text{ mol H}_2}{2 \text{ mol HCl}} \right) \left( 22.4 \text{ L/mol} \right) = 30.7 \text{ L H}_2$$

$\therefore$  30.7 L H<sub>2</sub> is produced

Zn is in excess

$$\left( \frac{100.0 \text{ g HCl}}{36.46094 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Zn}}{2 \text{ mol HCl}} \right) (65.38 \text{ g/mol}) = 89.7 \text{ g Zn needed}$$

$$130.0 \text{ g} - 89.7 \text{ g} = \underline{40.3 \text{ g Zn in excess}}$$

14. 29.6 mL of 0.350 M sodium hydroxide are required to titrate 20.0 mL of phosphoric acid. Calculate the molarity of the phosphoric acid.  $3 \text{ NaOH} + \text{H}_3\text{PO}_4 \rightarrow \text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O}$

$$C_a = ?$$

$$V_a = 20.0 \text{ mL}$$

$$R_a = 1$$

$$C_b = 0.350 \text{ M}$$

$$V_b = 29.6 \text{ mL}$$

$$R_b = 3$$

$$C_a = \frac{C_b V_b R_a}{V_a R_b} = \frac{(0.350 \text{ M})(0.0296 \text{ L})(1)}{(0.0200 \text{ L})(3)}$$

$$= \underline{0.173 \text{ mol/L H}_3\text{PO}_4}$$

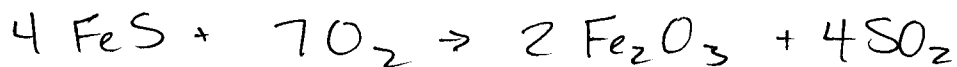
15. What mass of copper(II) hydroxide is precipitated by the reaction of 2.67 g of potassium hydroxide with copper(II) nitrate?  $2 \text{ KOH} + \text{Cu}(\text{NO}_3)_2 \rightarrow \text{Cu}(\text{OH})_2 + 2 \text{ KNO}_3$

$$\left( \frac{2.67 \text{ g KOH}}{56.10564 \text{ g/mol}} \right) \left( \frac{1 \text{ mol Cu}(\text{OH})_2}{2 \text{ mol KOH}} \right) (97.56068 \text{ g/mol})$$

$$= \underline{2.32 \text{ g Cu}(\text{OH})_2}$$



19. Iron(II) sulfide reacts with oxygen gas to produce iron(III) oxide and sulfur dioxide. What mass of iron(III) oxide is produced from the reaction of 20.0 g of iron(II) sulfide and 14.1 g of oxygen? Which reactant is in excess, and how much remains unreacted?



$$\left( \frac{20.0 \text{ g FeS}}{87.913 \text{ g/mol}} \right) \left( \frac{2 \text{ mol Fe}_2\text{O}_3}{4 \text{ mol FeS}} \right) (159.6922 \text{ g/mol}) = 18.2 \text{ g}$$

$$\left( \frac{14.1 \text{ g O}_2}{31.9988 \text{ g/mol}} \right) \left( \frac{2 \text{ mol Fe}_2\text{O}_3}{7 \text{ mol O}_2} \right) (159.6922 \text{ g/mol}) = 20.1 \text{ g}$$

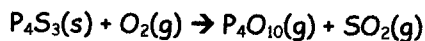
$\therefore$  18.2 g  $\text{Fe}_2\text{O}_3$  is produced

FeS is limiting,  $\text{O}_2$  is in excess

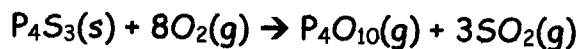
$$\left( \frac{20.0 \text{ g FeS}}{87.913 \text{ g/mol}} \right) \left( \frac{7 \text{ mol O}_2}{4 \text{ mol FeS}} \right) (31.9988 \text{ g/mol}) = 12.7 \text{ g O}_2 \text{ needed}$$

$$14.1 \text{ g available} - 12.7 \text{ g needed} = \frac{1.4 \text{ g O}_2}{\text{in excess}}$$

20. The chemical equation below describes what happens when a match is struck against a rough surface to produce light and heat.



- a) Balance this chemical equation



- b) If 5.3 L of oxygen gas at STP were consumed, what volume of sulfur dioxide at STP would be produced?

$$\left( \frac{5.3 \text{ L O}_2}{22.4 \text{ L/mol}} \right) \left( \frac{3 \text{ mol SO}_2}{8 \text{ mol O}_2} \right) \left( 22.4 \frac{\text{L}}{\text{mol}} \right) = 1.9875$$

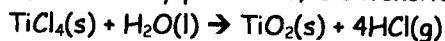
$$= 2.0 \text{ L SO}_2$$

- c) What mass of  $\text{P}_4\text{S}_3$  would be consumed in the same reaction described in (b)?

$$\left( \frac{5.3 \text{ L O}_2}{22.4 \text{ L/mol}} \right) \left( \frac{1 \text{ mol P}_4\text{S}_3}{8 \text{ mol O}_2} \right) \left( 220.09304 \frac{\text{g}}{\text{mol}} \right) = 6.5094$$

$$= 6.5 \text{ g P}_4\text{S}_3$$

21. Titanium(IV) chloride reacts violently with water vapour to produce titanium(IV) oxide and hydrogen chloride gas. Titanium(IV) oxide, when finely powdered, is extensively used in paint as a white pigment.



The reaction has been used to create smoke screens. In moist air, the titanium(IV) chloride reacts to produce a thick smoke of suspended titanium(IV) oxide particles. What mass of titanium(IV) oxide can be expected when 85.6 g of titanium(IV) chloride is reacted with excess water vapour?

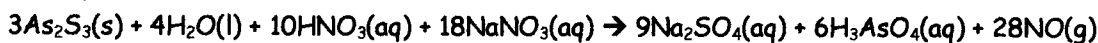
$$\left( \frac{85.6 \text{ g TiCl}_4}{189.692 \text{ g/mol}} \right) \left( \frac{1 \text{ mol TiO}_2}{1 \text{ mol TiCl}_4} \right) \left( 79.8788 \frac{\text{g}}{\text{mol}} \right)$$

$$= 36.0459$$

$$= 33.0 \text{ g TiO}_2$$



22. 1.56 g of  $\text{As}_2\text{S}_3$ , 0.140 g of  $\text{H}_2\text{O}$ , 1.23 g of  $\text{HNO}_3$ , and 3.50 g of  $\text{NaNO}_3$  are reacted according to the equation below:



a) What mass of  $\text{H}_3\text{AsO}_4$  is produced?

$$\left( \frac{1.56 \text{ g } \text{As}_2\text{S}_3}{246.0412 \text{ g/mol}} \right) \left( \frac{6 \text{ mol } \text{H}_3\text{AsO}_4}{3 \text{ mol } \text{As}_2\text{S}_3} \right) \left( \frac{141.94302 \text{ g}}{\text{mol}} \right) = 1.80 \text{ g}$$

$$\left( \frac{0.140 \text{ g } \text{H}_2\text{O}}{18.01528 \text{ g/mol}} \right) \left( \frac{6 \text{ mol } \text{H}_3\text{AsO}_4}{4 \text{ mol } \text{H}_2\text{O}} \right) \left( \frac{141.94302 \text{ g}}{\text{mol}} \right) = 1.65 \text{ g}$$

$$\left( \frac{1.23 \text{ g } \text{HNO}_3}{63.01284 \text{ g/mol}} \right) \left( \frac{6 \text{ mol } \text{H}_3\text{AsO}_4}{10 \text{ mol } \text{HNO}_3} \right) \left( \frac{141.94302 \text{ g}}{\text{mol}} \right) = 1.66 \text{ g}$$

$$\left( \frac{3.50 \text{ g } \text{NaNO}_3}{84.99467 \text{ g/mol}} \right) \left( \frac{6 \text{ mol } \text{H}_3\text{AsO}_4}{18 \text{ mol } \text{NaNO}_3} \right) \left( \frac{141.94302 \text{ g}}{\text{mol}} \right) = 1.95 \text{ g}$$

$\therefore \text{H}_2\text{O}$  is the limiting reactant and 1.65 g  $\text{H}_3\text{AsO}_4$  is produced

b) What volume (at STP) of  $\text{NO}$  is produced?

$$\left( \frac{0.140 \text{ g } \text{H}_2\text{O}}{18.01528 \text{ g/mol}} \right) \left( \frac{28 \text{ mol } \text{NO}}{4 \text{ mol } \text{H}_2\text{O}} \right) \left( \frac{22.4 \text{ L/mol}}{\text{mol}} \right) = 1.22 \text{ L of NO}$$