3. Hydrofluoric acid solutions cannot be stored in glass containers because HF reacts readily with silica in glass to produce hexafluorosilicic acid (H_2SiF_6).

$$SiO_2(s) + 6HF(aq) \rightarrow H_2SiF_6(aq) + 2H_2O(l)$$

If 40.0 kg silicon dioxide and 40.0 kg of HF react:

a. Determine the mass of the excess reactant remaining.

$40.0\text{ kg } SiO_2 \times \frac{1{,}000\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol}}{60.09\text{ g}} = \frac{666\text{ mol } SiO_2}{1} = 666$

limiting!

$40.0\text{ kg } HF \times \frac{1{,}000\text{ g}}{1\text{ kg}} \times \frac{1\text{ mol}}{20.008\text{ g}} = \frac{1{,}999\text{ mol}}{6} = 333$

Smaller!

	SiO_2	+ 6HF	→ H_2SiF_6	+ $2H_2O$
B	666	1,999	Ø	Ø
C	-333	-1,999	+333	+666
A	333	Ø	333	666

$333\text{ mol } SiO_2 \times \frac{60.09\text{ g}}{1\text{ mol}} = 20{,}010\text{ g}$

$= 2.00 \times 10^4\text{ g}$ (3 sf) or 20.0 kg SiO_2 left over

b. Determine the theoretical yield of hexafluorosilicic acid.

$333\text{ mol } H_2SiF_6 \times \frac{144.106\text{ g}}{1\text{ mol}} = 47{,}987$

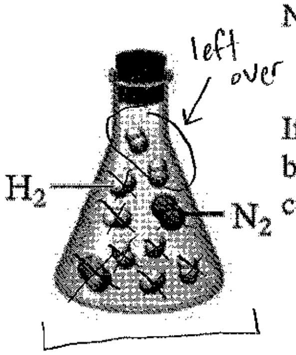
$= 4.80 \times 10^4\text{ g}$ or 48.0 kg H_2SiF_6

c. Determine the percent yield if the actual yield is 45.8 kg H_2SiF_6.

$\%\text{ yield} = \frac{act}{th} \times 100 = \frac{45.8}{48.0} \times 100 = 95.4\%$

Multiple Choice Practice

4.

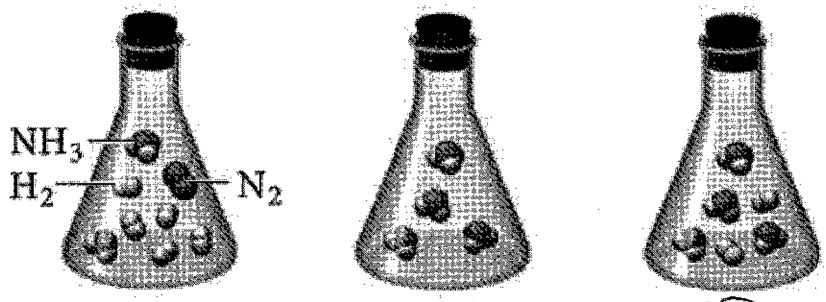


Nitrogen and hydrogen gas react to form ammonia according to the reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2\,NH_3(g)$$

If a flask contains a mixture of reactants represented by the image at right, which image below best represents the mixture in the flask after the reactants have reacted as completely as possible? What is the limiting reactant? Which reactant is in excess?

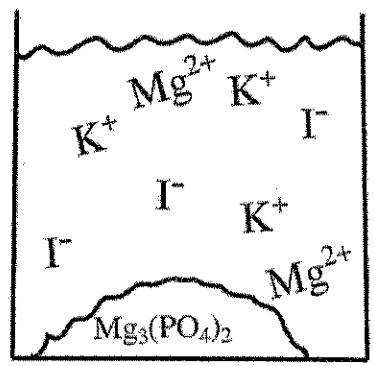
cross-out method:
2 rxns = crossed
out 2 N_2, 6 H_2
⇒ 2 H_2 left over



(a) (b) (c)

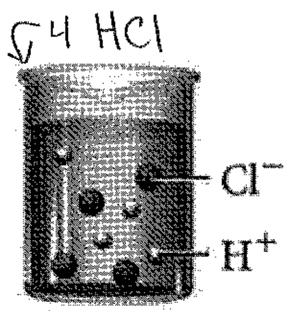
5. Based on the particulate drawing of the products for the reaction below, which reactant is limiting for the following reaction and why?

$$2\,K_3PO_4(aq) + 3\,MgI_2(aq) \rightarrow Mg_3(PO_4)_2(s) + 6\,KI(aq)$$

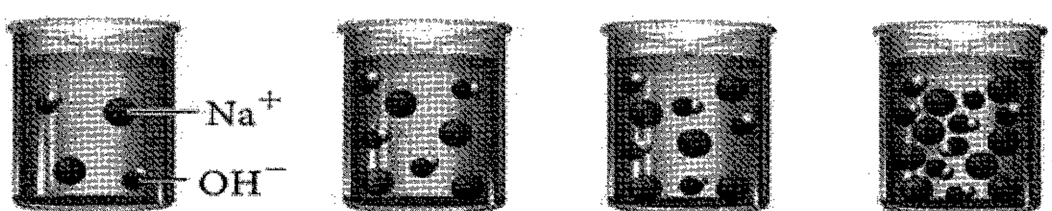


a. The K_3PO_4, because there are no excess PO_4^{3-} ions after the reaction.
b. The MgI_2, because there are excess Mg^{2+} cations remaining after the reaction.
c. The K_3PO_4, because it contains a cation that cannot form a precipitate.
d. The MgI_2, because it required more of itself to create the products.

6. A hydrochloric acid solution will neutralize a sodium hydroxide solution. Look at the molecular views showing one beaker of HCl and four beakers of NaOH. Which NaOH beaker will just neutralize the HCl beaker? Begin by writing a balanced chemical equation for the neutralization reaction.



$\underline{1}\,HCl_{(aq)} + \underline{1}\,NaOH_{(aq)} \rightarrow \underline{1}\,H_2O_{(l)} + \underline{1}\,NaCl$



(a) (b) (c) (d)

1:1

limiting! (2:1)

7. What is the maximum grams of CO_2 (molar mass 44.0 g/mol) that can be produced from 50.0 mol each of sulfuric acid and sodium hydrogen carbonate? The balanced equation is:

$$2\ \mathrm{NaHCO_3} + \mathrm{H_2SO_4} \rightarrow 2\ \mathrm{CO_2} + 2\ \mathrm{H_2O} + \mathrm{Na_2SO_4}$$

a. (50.0) (1/2) (44.0)
b. (50.0) (44.0)
c. (50.0) (4) (44.0)
d. (50.0) (2) (44.0)

$$50 \text{ mol NaHCO}_3 \times \frac{2 \text{ mol CO}_2}{2 \text{ mol NaHCO}_3} \times \frac{44 \text{ g CO}_2}{1 \text{ mol CO}_2} = 50 \times 44$$

8. The reaction of silver metal and dilute nitric acid proceeds according to the equation below. If 0.10 mol of powdered silver is added to 10. mL of 6.0 molar nitric acid, the number of moles of NO gas that can be formed is:

$$3\ \mathrm{Ag}(s) + 4\ \mathrm{HNO_3}(aq) \leftrightarrow 4\ \mathrm{AgNO_3}(aq) + \mathrm{NO}(g) + 2\ \mathrm{H_2O}(l)$$

a. 0.015 mol
b. 0.030 mol
c. 0.045 mol
d. 0.020 mol

$$\text{mol}_{HNO_3} = M \times L = 6M \times 0.01L = 0.06 \text{ mol HNO}_3 \times \frac{1 \text{ mol NO}}{4 \text{ mol HNO}_3} = \frac{6}{4} \times 0.01 = 0.015$$

limiting! b/c

$$\frac{0.06}{4} = 0.015 \quad \frac{0.10}{3} \approx 0.033$$

Smaller!

$\Rightarrow HNO_3$ limiting

9. 250. mL of 0.30 M hydrochloric acid is combined with 250. mL of 0.10 M K_2S in the gas evolution shown below.

$$2\ \mathrm{HCl}(aq) + \mathrm{K_2S}(aq) \rightarrow \mathrm{H_2S}(g) + 2\ \mathrm{KCl}(aq)$$

What is the concentration of K^+ ions in the KCl solution formed during this reaction?

a. 0.050 M
b. 0.10 M
c. 0.15 M
d. 0.30 M

mmol HCl > mmol K_2S $\Rightarrow$ K_2S limiting!

$$\frac{250 \times 0.3}{2} > \frac{250 \times 0.1}{1}$$

$$250 \times 0.1 = 25 \text{ mmol K}_2\text{S} \times \frac{2\ K^+}{1\ K_2S} = 50 \text{ mmol } K^+$$

$$[K^+] = \frac{50 \text{ mmol}}{500 \text{ mL}} = 0.1 \text{ M}$$

10. Which of the following statements about the reaction below is **false**?

1 mol   2 mol $CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(g)$

✓ a. Every methane molecule that reacts produces two water molecules.

✓ b. If 16.0 g of methane react with 64.0 g of molecular oxygen, the combined masses of the products will be 80.0 g.

(c.) If 11.2 L of methane react with an excess of molecular oxygen, the volume of CO_2 produced at STP is (44/16)(11.2) liters.

✓ d. If 22.4 L of methane at STP react with 64.0 g of molecular oxygen, 22.4 L of CO_2 at STP can be produced.

1 mol   2 mol O_2 1 mol

actual yield

11. When 12 g of methanol (CH_3OH) was treated with excess oxidizing agent (MnO_4^-), 14 g of formic acid (HCOOH) was obtained. Using the following chemical equation, calculate the percent yield.

$$3\,CH_3OH + 4\,MnO_4^- \rightarrow 3\,HCOOH + 4\,MnO_2$$

a. 100%   b. 92%   (c.) 82%   d. 70%

$$12\,g\,CH_3OH \times \frac{1\,mol\,CH_3OH}{32\,g\,CH_3OH} \times \frac{3\,mol\,HCOOH}{3\,mol\,CH_3OH} \times \frac{46\,g\,HCOOH}{1\,mol\,HCOOH} = \frac{12 \cdot 46}{32} \approx 12 \cdot 1.5 = 18$$

~1.5 (but ↓)

$$\%\,yield = \frac{14}{18} \times 100 = \frac{7}{9} \times 100 \approx 80\%$$

12. How many grams of NH_3 can be prepared from 77.3 g of N_2 and 14.2 g of H_2?

a. 47.0 g   (b.) 79.7 g   c. 93.9 g   d. 120. g

$$N_2 + 3H_2 \rightarrow 2NH_3$$

$$\frac{77.3\,g\,N_2}{28\,g/mol} \approx 3/1 = 3$$

$$\frac{14.2\,g\,H_2}{2\,g/mol} = 7/3 = 2\tfrac{1}{3}$$

H_2 ← limiting; $2\tfrac{1}{3}$ Smaller!

$$14.2\,g\,H_2 \times \frac{1\,mol\,H_2}{2\,g\,H_2} \times \frac{2\,mol\,NH_3}{3\,mol\,H_2} \times \frac{17\,g\,NH_3}{1\,mol\,NH_3}$$

$$\approx \frac{14 \cdot 17}{3} = 14 \cdot 6 = 84\,g$$

~6 (but ↓)