Problem Set #2

CHEM101A: General College Chemistry

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1 Topic A Problem 12

What mass of Fe_2O_3 would react with 20.00 g of Zn? The chemical equation for this reaction is:

$$3\,\mathrm{Zn} + \mathrm{Fe_2O_3} \longrightarrow 2\,\mathrm{Fe} + 3\,\mathrm{ZnO} \tag{1}$$

1.1 Solution

The simple stoichiometry is the way to go here.

$$20.00\mathrm{g} \times \frac{1\,\mathrm{mol\,Zn}}{65.38\mathrm{g}} \times \frac{1\,\mathrm{Fe_2O_3}}{3\,\mathrm{Zn}} \times \frac{159.7\,\mathrm{g\,Fe_2O_3}}{1\,\mathrm{mol\,Fe_2O_3}} = \boxed{16.28\,\mathrm{g\,Fe_2O_3}} \tag{2}$$

2 Topic A Problem 13

x moles of C_4H_{10} reacts with oxygen according to the following equation:

$$2\,C_4H_{10} + 13\,O_2 \longrightarrow 8\,CO_2 + 10\,H_2O \tag{3}$$

a) How many moles of water are formed?
b) How many moles of oxygen are consumed?

2.1 Solution (a)

The ratio of C_4H_{10} used to H_2O created in this reaction is 1:5. With x moles of C_4H_{10}, that would gives us $\boxed{5x\,\mathrm{mol}\,H_2O}$.

2.2 Solution (b)

The ratio of C_4H_{10} used to O_2 consumed in this reaction is 2:13. With x moles of C_4H_{10}, that would gives us $\boxed{\frac{13}{2}x\,\mathrm{mol}\,O_2}$.

3 Topic A Problem 14

10.00 g of N_2 is mixed with 33.61 g of F_2, and the elements react according to the following equation:

$$\mathrm{N_2 + 3\,F_2 \longrightarrow 2\,NF_3} \tag{4}$$

a) Which element is the limiting reactant?
b) What is the theoretical yield of NF_3?
c) If the reaction goes to completion, how many grams of the excess reactant will remain?
d) Set up an ICE table for this reaction.

3.1 Solution (a)

First, we calculate the theoretical yields for each for the reactants.

$$m_{\mathrm{N_2}} = 10.00\,\mathrm{g} \times \frac{1\,\mathrm{mol\,N_2}}{28.02\,\mathrm{g\,N_2}} \times \frac{2\,\mathrm{NF_3}}{1\,\mathrm{N_2}} \times \frac{71.01\,\mathrm{g\,NF_3}}{1\,\mathrm{mol\,NF_3}} = 50.69\,\mathrm{g\,NF_3} \tag{5}$$

$$m_{\mathrm{F_2}} = 33.61\,\mathrm{g} \times \frac{1\,\mathrm{mol\,F_2}}{38.00\,\mathrm{g\,F_2}} \times \frac{2\,\mathrm{NF_3}}{3\,\mathrm{F_2}} \times \frac{71.01\,\mathrm{g\,NF_3}}{1\,\mathrm{mol\,NF_3}} = 41.87\,\mathrm{g\,NF_3} \tag{6}$$

With a lower final mass, $\boxed{\mathrm{F_2}}$ is the limiting reactant.

3.2 Solution (b)

The theoretical yield was found in part (a). $\boxed{41.87\,\mathrm{g\,NF_3}}$

3.3 Solution (c)

Use a similar strategy to part (a).

$$33.61\,\mathrm{g} \times \frac{1\,\mathrm{mol\,F_2}}{38.00\,\mathrm{g\,F_2}} \times \frac{1\,\mathrm{N_2}}{3\,\mathrm{F_2}} \times \frac{28.02\,\mathrm{g\,N_2}}{1\,\mathrm{mol\,N_2}} = 8.261\,\mathrm{g\,NF_3} \tag{7}$$

Subtract this from the available mass of N_2 to get the final N_2.

$$10.00\,\mathrm{g\,N_2} - 8.261\,\mathrm{g\,N_2} = \boxed{1.74\,\mathrm{g\,N_2}} \tag{8}$$

3.4 Solution (d)

I used tabular for this table. Please excuse any poor or improper formatting.

mol	$\mathrm{N_2}$	$\mathrm{+\,3\,F_2}$	$\mathrm{\longrightarrow 2\,NF_3}$
I	0.3569	0.8844	0
C	-0.2948	-0.8844	0.5896
E	0.0621	0	0.5896

For those interested in how I went about getting these values, I can explain. I started with the initial mass of F_2, which has been previously established to be the limiting reactant, and converted that to moles. I did (roughly) the same thing for the known quantity of N_2 initially. We also start with no NF_3. Assuming the percentage yield to be 100%, every mole of F_2 would be used, so the Change row for F_2 would be the negative of the initial quantity of F_2. Multiply that by the ratio of N_2 to F_2 ($\frac{1}{3}$) to get the Change row of N_2. The same can be done for NF_2, just taking the negative thereof and with a ratio of $\frac{2}{3}$ instead of $\frac{1}{3}$. With all of this, we only have to add the initial and the change together (respecting the positive or negative signs) to get the values for the End row.

4 Topic A Problem 15

a) If 58.26 g of iodine reacts with excess aluminum, what is the theoretical yield of aluminum iodide? The reaction is $2\,\mathrm{Al} + 3\,\mathrm{I_2} \longrightarrow 2\,\mathrm{AlI_3}$.
b) If 56.11 g of aluminum iodide is actually formed in the reaction in part a, what is the percent yield of aluminum iodide?

4.1 Solution (a)

Watch me use the power of Stiochiometry Magic.

$$58.26\,\mathrm{g} \times \frac{1\,\mathrm{mol\,I_2}}{253.8\,\mathrm{g\,I2}} \times \frac{2\,\mathrm{AlI_3}}{3\,\mathrm{I_2}} \times \frac{407.68\,\mathrm{g\,AlI_3}}{1\,\mathrm{mol\,AlI_3}} = \boxed{62.39\,\mathrm{g\,AlI_3}} \tag{9}$$

4.2 Solution (b)

Here we use the formula for the pecent yield.

$$\mathrm{PY} = \frac{\mathrm{AY}}{\mathrm{TY}} \times 100\% = \frac{56.11\,\mathrm{g}}{62.39\,\mathrm{g}} \times 100\% = 0.8994 \times 100\% = \boxed{89.94\%} \tag{10}$$

5 Topic A Problem 16

A chemist mixes 16.00 g of HCl with 10.00 g of Mg and obtains an 81.3% yield of $MgCl_2$. What mass of $MgCl_2$ did the chemist obtain? The chemical reaction is:

$$\mathrm{Mg} + 2\,\mathrm{HCl} \longrightarrow \mathrm{MgCl_2} + \mathrm{H_2} \tag{11}$$

5.1 Solution

First calculate the theoretical yield of $MgCl_2$ in the cases of HCl and Mg being the limiting reactants.

$$MM(\mathrm{MgCl_2}) = 24.31\,\mathrm{g/mol} + 2 * 35.45\,\mathrm{g/mol} = 95.21\,\mathrm{g/mol} \tag{12}$$

$$MM(\mathrm{HCl}) = 1.008\,\mathrm{g/mol} + 35.45\,\mathrm{g/mol} = 36.458\,\mathrm{g/mol} \tag{13}$$

$$m_{\mathrm{Mg}} = 10.00\,\mathrm{g} \times \frac{1\,\mathrm{mol\,Mg}}{24.31\,\mathrm{g\,Mg}} \times \frac{1\,\mathrm{MgCl_2}}{1\,\mathrm{Mg}} \times \frac{95.21\,\mathrm{g\,MgCl_2}}{1\,\mathrm{mol\,MgCl_2}} \tag{14}$$

$$= 39.16\,\mathrm{g\,MgCl_2} \tag{15}$$

$$m_{\mathrm{HCl}} = 16.00\,\mathrm{g} \times \frac{1\,\mathrm{mol\,HCl}}{36.458\,\mathrm{g\,HCl}} \times \frac{1\,\mathrm{MgCl_2}}{2\,\mathrm{HCl}} \times \frac{95.21\,\mathrm{g\,MgCl_2}}{1\,\mathrm{mol\,MgCl_2}} \tag{16}$$

$$= 20.89\,\mathrm{g\,MgCl_2} \tag{17}$$

The latter is lower, so the HCl would be the limiting reactant and 20.89 g $MgCl_2$ would be the theoretical yield. Multiplying this by the (decimal version of) the percetage yield to get the actual yield.

$$20.89\,\mathrm{g\,MgCl_2} * 0.813 = \boxed{17.0\,\mathrm{g\,MgCl_2}} \tag{18}$$

6 Topic A Problem 17

How many milliliters of liquid Br_2 (density = 3.1 g/mL) will react with 6.143 g of Cr, if the product of this reaction is $CrBr_3$?

6.1 Solution

First write a chemical equation for this and balance it.

$$3\,Br_2 + 2\,Cr \longrightarrow 2\,CrBr_3$$

The rest of the path is paved with the magic of Stoichiometry.

$$6.143\,g\,Cr \times \frac{1\,mol\,Cr}{52.00\,g\,Cr} \times \frac{3\,Br_2}{2\,Cr} \times \frac{159.8\,g\,Br_2}{1\,mol\,Br_2} \times \frac{1\,mL}{3.1\,g} = \boxed{9.1\,mL\,Br_2} \tag{19}$$

7 Topic A Problem 18

Ethane (C_2H_6) reacts with oxygen according to the following chemical equation:

$$2\,C_2H_6 + 7\,O_2 \longrightarrow 4\,CO_2 + 6\,H_2O \tag{20}$$

a) If you mix 5 moles of C_2H_6 with 13 moles of O_2, how many moles of each substance will you end up with, assuming the reaction goes to completion? Include an ICE table in your answer.
b) If you mix 81.43 g of C_2H_6 with 194.60 g of O_2, how many grams of each substance will you end up with, assuming the reaction goes to completion? Include an ICE table in your answer. (Note: your ICE table should be in terms of moles.)
c) A chemist mixes 3.414 moles of O_2 with an unknown number of moles of C_2H_6. The chemist obtains 1.657 moles of O_2. How many moles of C_2H_6 must have been present originally, assuming the reaction went to completion? Include an ICE table in your answer.

7.1 Solution (a)

mol	$2\,C_2H_6$	+	$7\,O_2$	$\longrightarrow$	$4\,CO_2$	+	$6\,H_2O$
I	5		13		0		0
C	$-\frac{26}{7}$		-13		$\frac{52}{7}$		$\frac{78}{7}$
E	$\frac{9}{7}$		0		$\frac{52}{7}$		$\frac{78}{7}$

You will end up with $\boxed{1.286\,\mathrm{mol}\,C_2H_6}$, $\boxed{0\,\mathrm{mol}\,O_2}$, $\boxed{7.429, \mathrm{mol}\,CO_2}$, and $\boxed{11.143\,\mathrm{mol}\,H_2O}$.

7.2 Solution (b)

mol	$2\,C_2H_6$	+	$7\,O_2$	$\longrightarrow$	$4\,CO_2$	+	$6\,H_2O$
I	2.708		6.081		0		0
C	-1.737		-6.081		3.475		5.212
E	0.971		0		3.475		5.212

Final table

Calculations
Convert grams to moles for oxygen and ethane.

$$n(O_2) = \frac{m}{MM} = \frac{194.60\,\mathrm{g}\,O_2}{32.00\,\mathrm{g/mol}} = 6.08125\,\mathrm{mol}\,O_2 \tag{21}$$

$$n(C_2H_6) = \frac{m}{MM} = \frac{81.43\,\mathrm{g}\,C_2H_6}{30.068\,\mathrm{g/mol}} = 2.708194759\,\mathrm{mol}\,C_2H_6 \tag{22}$$

Next, we check which would result in the most product, for the coefficient c of each reactant.

$$ML = \frac{n}{c} \tag{23}$$

$$ML(\mathrm{O_2}) = \frac{6.08125\,\mathrm{mol\,O_2}}{7\,\mathrm{O_2}} = 0.86875\,\mathrm{mol} \tag{24}$$

$$ML(\mathrm{C_2H_6}) = \frac{2.708194759\,\mathrm{mol\,C_2H_6}}{2\,\mathrm{C_2H_6}} = 1.357\,\mathrm{mol} \tag{25}$$

This makes the O_2 the limiting reactant. We can just fill out the ICE table's 'C' (change) values from here by using ratios of coefficients of reactants and products. I won't go write all my calculations here, but they tend to have a simple formula.

$$n_2 = n_1 * \frac{c_2}{c_1} \tag{26}$$

This leads into the filling out of the bottom row (end), with a simple formula, E = I + C. From here, all we need to do is convert moles to grams.

$$MM(\mathrm{C_2H_6}) = 2 * 12.01\,\mathrm{g/mol} + 6 * 1.008\,\mathrm{g/mol} = 30.068\,\mathrm{g/mol} \tag{27}$$

$$MM(\mathrm{O_2}) = 2 * 16.00\,\mathrm{g/mol} = 32.00\,\mathrm{g/mol} \tag{28}$$

$$MM(\mathrm{CO_2}) = 12.01 + 2 * 16.00\,\mathrm{g/mol} = 44.01\,\mathrm{g/mol} \tag{29}$$

$$MM(\mathrm{H_2O}) = 2 * 1.008\,\mathrm{g/mol} + 16.00\,\mathrm{g/mol} = 18.016\,\mathrm{g/mol} \tag{30}$$

$$m = MM * n \tag{31}$$

$$m(\mathrm{C_2H_6}) = 30.068\,\mathrm{g/mol\,C_2H_6} * 0.971\,\mathrm{mol} = \boxed{29.20\,\mathrm{g\,C_2H_6}} \tag{32}$$

$$m(\mathrm{O_2}) = 32.00\,\mathrm{g/mol\,O_2} * 0\,\mathrm{mol} = \boxed{0\,\mathrm{g\,O_2}} \tag{33}$$

$$m(\mathrm{CO_2}) = 44.01\,\mathrm{g/mol\,CO_2} * 3.475\,\mathrm{mol} = \boxed{152.9\,\mathrm{g\,CO_2}} \tag{34}$$

$$m(\mathrm{H_2O}) = 18.016\,\mathrm{g/mol\,H_2O} * 5.212\,\mathrm{mol} = \boxed{93.90\,\mathrm{g\,H_2O}} \tag{35}$$

7.3 Solution (c)

We'll just put together an ICE table and fill it out until we have enough information to get the answer. We don't even need to fill it out completely.

mol	$2\,C_2H_6$	+	$7\,O_2$	$\longrightarrow$	$4\,CO_2$	+	$6\,H_2O$
I	0.502		3.414		0		0
C	-0.502		-1.757				
E	0		1.657				

I have a few steps I made for this.

1. We can start by filling out our knowns. In the interest of candor, we don't even know if the initial amount of CO_2 and H_2O is 0, that's just an assumption I made.

2. Since the O_2 has some left over at the end, it is definitely not the limiting reactant. That makes C_2H_6 the limiting reactant, so none of it should be left by the end and we can fill that out.

3. The formula of C = E - I can be applied for Oxygen, giving us our change in O_2.

   - If you ever took Physics or Calculus (maybe even Algebra), you'll recognize this as equivalent to $\Delta x = x_f - x_i$.

4. We can use the coefficient ratio mentioned in part (b), this time $\frac{2}{7}$, for the change in C_2H_6.

5. The formula C = E - I can be turned into I = E - C to get initial quantity of C_2H_6.

With everything filled out, we have the final answer of $\boxed{0.502\,\mathrm{mol}\,C_2H_6}$

8 Topic A Problem 19

Ammonia reacts with oxygen according to the following chemical equation:

$$4\,NH_3 + 3\,O_2 \longrightarrow 2\,N_2 + 6\,H_2O \tag{36}$$

Suppose you mix x moles of NH_3 with y moles of O_2.
a) If NH_3 is the limiting reactant, how many moles of each substance will you end up with, assuming the reaction goes to completion? Include an ICE table in your answer.
b) If O_2 is the limiting reactant, how many moles of each substance will you end up with, assuming the reaction goes to completion? Include an ICE table in your answer.
c) If you end up with 0.4y moles of O_2, what must the relationship be between x and y, assuming the reaction goes to completion?

8.1 Solution

9 Topic A Problem 20

You have x grams of $Na_2Cr_2O_7$. How many grams of CrCl3 will be formed if the $Na_2Cr_2O_7$ undergoes the reaction below? Express your answer in terms of x.

$$Na_2Cr_2O_7 + 3\,Zn + 14\,HCl \longrightarrow 2\,CrCl_3 + 3\,ZnCl_2 + 2\,NaCl + 7\,H_2O \tag{37}$$

9.1 Solution

10 Topic A Problem 21

A metal sample weighing 1.410 g contains a mixture of copper and aluminum. When excess HCl is added to this sample, the aluminum reacts as follows:

$$2\,\mathrm{Al} + 6\,\mathrm{HCl} \longrightarrow 2\,\mathrm{AlCl_3} + 3\,\mathrm{H_2} \tag{38}$$

849 mL of H_2 (density 0.08264 g/L) is produced. Calculate the mass percentage of each element in the original sample. Note that copper does not react with HCl.

10.1 Solution

11 Topic A Problem 22

A chemist has a mixture of $AgNO_3$ and KNO_3 that weighs a total of 4.177 g. The chemist dissolves the mixture in water and then adds a solution of NaOH. The AgNO3 reacts with the NaOH as follows:

$$2\,AgNO_3(aq) + 2\,NaOH(aq) \longrightarrow Ag_2O(s) + 2\,NaNO_3(aq) + H_2O(l) \qquad (39)$$

The chemist finds that 1.080 grams of Ag_2O were formed. Calculate the mass percentages of $AgNO_3$ and KNO_3 in the original mixture. (Note that KNO_3 does not react with NaOH.)

11.1 Solution

12 Topic A Problem 23

A 25.000 g sample of sulfur is burned. Some of the sulfur reacts to form SO_2:

$$S + O_2 \longrightarrow SO_2 \tag{40}$$

The rest of the sulfur reacts to form SO_3:

$$2\,S + 3\,O_2 \longrightarrow 2\,SO_3 \tag{41}$$

The total mass of products (SO_2 and SO_3) is 58.723 g. Calculate the masses of SO_2 and SO_3 in this mixture.

12.1 Solution

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