"A" students work (without solutions manual) ~ 10 problems/night.

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FITCH Rules

General

G1: Suzuki is Success

G2. Slow me down

G3. **Scientific Knowledge is Referential**

G4. Watch out for Red Herrings

G5. Chemists are Lazy

Chemistry

C1. It's all about charge

C2. Everybody wants to "be like Mike" (grp.18)

C3. Size Matters

C4. Still Waters Run Deep

C5. Alpha Dogs eat first

Particle	Symbol	Mass g	Amu
Neutron, n	${}^{1}_{0}n$	1.6749285x10^{-24}	1.00867
Proton, p	${}^{1}_{1}H$	1.6726231x10^{-24}	1.00728
Electron, e	${}^{0}_{-1}e$	1.093898x10^{-28}	0.00055

These numbers are inconvenient

Invoke General Rule #5:

Chemist's Are Lazy

$$1amu = \frac{mass\ of\ 1\ {}^{12}_{6}C\ atom}{12}$$

Create some unit (not g) that is more useful (atomic mass unit)

Invoke General Rule #3

There must be some reference state

$$1amu = \frac{1.9926x10^{-26}\ g}{12}$$

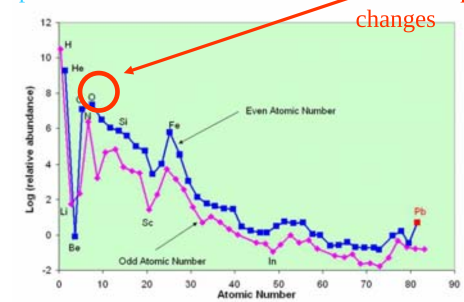
$$1amu = 1.66053873x10^{-24}\ g$$

Why a relative reference state of C12?

Represents a compromise between Physicists and Chemists

Physicists used a reference state of H1 to measure Relative velocities of gas phase atoms

Chemists used a reference state of O16 as an abundant element everything reacts with. Measured precipitate mass changes



C12 required
Least adjustments
To put both
Physics and chemistry
On same scale

Properties and Measurements

Property	Unit	Reference State
Size	m	size of earth
Volume	cm^3	m
Weight	gram	mass of 1 cm^3 water at specified Temp (and Pressure)
Temperature	^oC, K	boiling, freezing of water (specified Pressur
$1.66053873\text{x}10^{-24}$g	amu	mass of 1C12 atom/12

Expressing masses in terms of amu is more convenient

Two Examples we Examined already of STABLE isotopes

	% Abundance	Relative atomic mass (amu)
$^{204}_{82}Pb$	1.36	203.973
$^{206}_{82}Pb$	25.4	205.9745
$^{207}_{82}Pb$	21.1	206.9759
$^{208}_{82}Pb$	52.1	207.9766

	% Abundance	Relative atomic masses (amu
$^{12}_{6}C$	98.89	**12.0000**
$^{13}_{6}C$	1.11	13.00335

On the periodic table what is the reported atomic mass for lead?

Atomic mass= 207.2

Where did this number come from?

$$atomic\,mass_{average} = \sum_{isotopes}\left(\frac{\%_{isotope}}{100}\right)am_{isotope}$$

$$atomic\,mass_{Pb,average} = \frac{1.48\%}{100}(203.973) + \frac{23.6\%}{100}(205.9745) + \frac{22.6\%}{100}(206.9759) + \frac{52.3\%}{100}(207.9766)$$

$$atomic\,mass_{Pb,average} = 207.17709amu$$

On the periodic table what is the reported amu for C?

amu=12.01

Where did this number come from?

$$atomic\,mass_{average} = \sum_{isotopes}\left(\frac{\%_{isotope}}{100}\right)amu_{isotope}$$

$$atomic\,mass_{C,average} = \frac{1.1\%}{100}(13.00006) + \frac{98.9\%}{100}(11.99671)$$

$$atomic\,mass_{C,average} = 12.0077amu$$

$$atomic\,mass_{C,average} = 12.01amu$$

We saw that

$$\left(12g\ {}^{12}_{6}C\right)\left(\frac{1\ {}^{12}_{6}C\,atom}{12amu}\right)\left(\frac{1amu}{1.66053873x10^{-24}g}\right) = 6.022x10^{23}\ {}^{12}_{6}C\,atoms$$

General Rule #4: Chemists Are Lazy: make this number unique

$$N_{Avogadro} = mole = 6.022x10^{23}\ atoms$$

$$1 = \frac{mole}{6.022x10^{23}\,atoms}$$

$$\left(12g\ {}^{12}_{6}C\right)\left(\frac{1\ {}^{12}_{6}C\,atom}{12amu}\right)\left(\frac{1amu}{1.66053873x10^{-24}g}\right)\left(\frac{1mole}{6.022x10^{23}\,atoms}\right) = 1mole$$

$$\left((x = amu)\,g\ {}^{x}X_{elementX}\right) = 1mole\,atoms$$

Example

Element	Amu	Mass (g)	Moles (n)	# atoms
H	1.008	1.008	1	$6.022x10^{23}$
C	12.01	24.02	2	$12.044x10^{23}$
O	16.00	48.00	3	$18.066x10^{23}$
Pb	207.2	207.2	1	$6.022x10^{23}$

Properties and Measurements

Property	Unit	Reference State
Size	m	size of earth
Volume	cm^3	m
Weight	gram	mass of 1 cm^3 water at specified Temp (and Pressure)
Temperature	^oC, K	boiling, freezing of water (specified Pressur
$1.66053873x10^{-24}$g	amu	mass of 1C12 atom/12
$6.022x10^{23}$	mole	atomic mass of an element in **grams**

Molar Mass
in grams is numerically equal to the sum of the masses (in amu) of the atoms in the formula

$$MM = \sum_i n_i\left(amu_i\right) = a\left(amu_A\right) + b\left(amu_B\right) + \ldots\ldots z\left(amu_Z\right)$$

Example. Lead carbonate is principle component of white lead used in all white paints prior to WWII. Calculate the molar mass of lead carbonate

Lead carbonate = $PbCO_3$
principle component
before WWII
Molar mass= unknown

Element	#atoms	amu	Total amu
Pb	1	207.2	207.2
C	1	12.01	12.01
3O	3	16.00	48.00
			267.21
			267.2

$$MM = \sum_i n_i(amu_i) = a(amu_A) + b(amu_B) + ...z(amu_Z)$$

Example: Acetylsalicylic acid, $C_9H_8O_4$, is the active ingredient of aspirin. What is the mass in grams of 0.509 mol acetylsalicylic acid?

Acetylsalicylic acid
$C_9H_8O_4$
Active ingredient of aspirin
0.509 mol acetylsalicylic acid
Mass?

$$MM = \frac{m}{n}$$

$$(MM)n = m$$

$$\left(180.15\frac{g}{mole}\right)0.509mole = m = 91.7g$$

$$MM = \sum_i n_i(amu_i) = a(amu_A) + b(amu_B) + ...z(amu_Z)$$

$$MM = 9(12.01) + 8(1.008) + 4(16.00)$$

$$MM = 180.15\frac{g}{mole}$$

Mass %

$$\%element = (\#atoms\ \ of\ \ that\ \ element)\left[\frac{atomic\ \ weight\ \ of\ \ element}{molar\ mass\ \ of\ \ compound}\right](100\%)$$

Calcium carbonate, commonly called is used in many commercial products to relieve an upset stomach. It has the formula of $CaCO_3$. Because lead ore bodies form by substitution of lead onto old coral reefs (calcite or calcium carbonate) some antacid materials have been tested for their lead composition. What are the mass percents of Ca, C, and O in calcium carbonate?

$CaCO_3$
commercial product
upset stomach
mass percent Ca
mass percent C
mass percent O
old coral reefs
lead in antacids

Ca	40.08	40.08
C	12.01	12.01
3O	3(16.00)	48.00
		100.09

$$MM = \sum_i n_i(amu_i)$$

$$\%element = (\#atoms\ \ of\ \ that\ \ element)\left[\frac{atomic\ \ weight\ \ of\ \ element}{molar\ mass\ \ of\ \ compound}\right](100\%)$$

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Ca	40.08	40.08
C	12.01	12.01
3O	3(16.00)	48.00
		100.09

1 Ca

$$\%Ca = (1)\left[\frac{40.08}{100.09}\right]100\%$$

$$\%Ca = 40.04$$

$$\%C = 1\left[\frac{12.01}{100.09}\right]100\%$$

$$\%C = 11.9992\% = 12.00\%$$

$$\%O = 3\left[\frac{16.00}{100.09}\right]100\%$$

$$\%O = 47.95683885 = 47.96\%$$

Calcium carbonate, commonly called is used in many commercial products to relieve an upset stomach. It has the formula of $CaCO_3$. What are the mass percents of Ca, C, and O in calcium carbonate? Because lead ore bodies form by substitution of lead onto old coral reefs (calcite or calcium carbonate) some antacid materials have been tested for their lead composition.

Are We Done?

47.96
12.00
40.04
100%

Check answer

Very Important!

Converting between g, moles, and number of particles

$$nN_A = particles$$

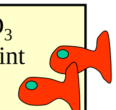
Mass=m — grams ←Molar Mass→ Moles=n — Moles ←Avogadro's Number→ particles — Formula Units

$$MM = \frac{m}{n}$$

The Golden Bridge
Stoichiometry or #of moles

Example. Lead carbonate is principle component of white lead used in all white paints prior to WWII. Determine the number of moles of lead carbonate in a sample of 14.8 g lead carbonate

Lead carbonate = $PbCO_3$
principle component paint before WWII
14.8 g $PbCO_3$
number of moles, n = unknown



Pb	207.2	207.2
C	12.01	12.01
3O	3(16.00)	48.00
		267.21
		267.2

$$MNM = \frac{m}{n}$$

$$n = \frac{m}{MM}$$

$$MM = \sum_i n_i(amu_i) = a(amu_A) + b(amu_B) + ...z(amu_Z)$$

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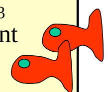


Pb	207.2	207.2
C	12.01	12.01
3O	3(16.00)	48.00
		267.21
		267.2

$$n = \frac{14.8g}{267.2\frac{g}{mole}}$$

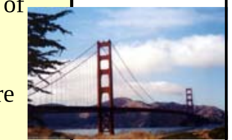
$$n = 0.055389221 mole$$

$$n = 0.0554 mole$$

Simplest Formula from Chemical Analysis

(Empirical)

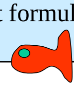
1. Mass scale is based on atomic number of C
2. Mass scale is therefore proportional to number of atoms or moles
3 Convert mass to moles = whole units of atoms
4. If moles are fractional this implies that atoms are fractional
   NOT ALLOWED by chemistry (remember we chemists do not break up atoms - that is reserved for physicists)
5. So multiply until we get whole number ratios



Example A 25.00-g sample of an orange compound contains 6.64 g of potassium, 8.84 g of chromium, and 9.52 g of oxygen. Find the simplest formula

(Empirical)

Total =25.00g
K= 6.64g
Cr=8.84 g
O=9.52 g
unknown - simplest formula
orange compound



CHECK THAT THE COMPOUND IS PURE!!

6.64
8.84
9.52
25.00

$$n(MM) = m$$

$$n = \frac{m}{MM}$$

This means that we have accounted for the total weight of The compound and we are confident in assigning weight Ratios.

Example : A 25.00-g sample of an orange compound contains 6.64 g of potassium, 8.84 g of chromium, and 9.52 g of oxygen. Find the simplest formula

(Empirical)

Sig fig

$$n = \frac{m}{MM}$$

$$\frac{6.64gK}{39.10\frac{gK}{(1)mole}} = n = 0.1698 molK = 0.170 molK$$

$$\frac{8.84gCr}{52.00\frac{gCr}{mol}} = n = 0.1700 molCr = 0.170 molCr$$

$$\frac{9.52gO}{16.00\frac{gO}{mol}} = n = 0.59500 molO = 0.595 molO$$

0.170molK
0.170molCr
0.595mol O

Simplest Formula from Chemical Analysis

(Empirical)

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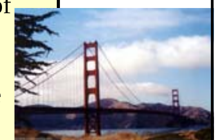


Example : A 25.00-g sample of an orange compound contains 6.64 g of potassium, 8.84 g of chromium, and 9.52 g of oxygen. Find the simplest formula

(Empirical)

0.170molK
0.170molCr
0.595mol O

7 O : 2K : 2Cr

Formula: Cations First

$$\frac{0.170 molCr}{0.170 molCr} = \frac{1.00 molCr}{1 molCr} \qquad \frac{2.00 molCr}{2 molCr}$$

2K : 2Cr : 7 O

$$\frac{0.170 molK}{0.170 molCr} = \frac{1.00 molK}{1 molCr} \qquad \frac{2.00 molK}{2 molCr}$$

$K_2Cr_2O_7$

$$\frac{0.595 molO}{0.170 molCr} = \frac{3.50 molO}{1 molCr} \qquad \frac{7.00 molO}{2 molCr}$$

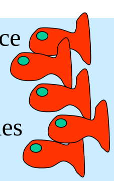
Make this non-fractional, multiply x2

Example : The compound that gives fermented grape juice, malt liquor, and vodka their intoxicating properties is ethyl alcohol, which contains the elements carbon, hydrogen, and oxygen.
When a sample of ethyl alcohol **is burned in air**, it is found that

5.00 g ethyl alcohol goes to 9.55 g CO_2 plus 5.87g H_2O

What is the simplest formula of ethyl alcohol?

Fermented grape juice
malt liquor
vodka
intoxicating properties
ethyl alcohol
elements C, H, O



5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?
burned in air

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What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O
Burned in air

All the C and H in the sample is converted **In air** (contains O_2) to CO_2 and H_2O

so g C in CO_2 represents g C in original ethyl alcohol
And g H in H2O represents g H original

$$5g_{total(C+H+O)} \xrightarrow{O_2} 9.55gCO_2 + 5.87gH_2O$$

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What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O

$$n = \frac{m}{MM} = m\left(\frac{1}{MM}\right)$$

$$n_C = (gCO_2)\left(\frac{moleCO_2}{amu\ gCO_2}\right)\left(\frac{1moleC}{1moleCO_2}\right)$$

$$n_C = (9.55gCO_2)\left(\frac{mole\ CO_2}{(12.01+2(16))gCO_2}\right)\left(\frac{moleC}{moleCO_2}\right)$$

$$n_C = (9.55gCO_2)\left(\frac{mole\ CO_2}{(44.01gCO_2)}\right)\left(\frac{moleC}{moleCO_2}\right)$$

$$n_C = 0.217mole$$

Example : The compound that gives fermented grape juice, malt liquor, and vodka their intoxicating properties is ethyl alcohol, which contains the elements carbon, hydrogen, and oxygen. When a sample of ethyl alcohol is burned in air, it is found that 5.00 g ethyl alcohol goes to 9.55 g CO_g plus 5.87g H_2O

What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O

$$n = \frac{m}{MM} = m\left(\frac{1}{MM}\right)$$

$$n_h = (gH_2O)\left(\frac{moleH_2O}{amu\ gH_2O}\right)\left(\frac{2moleH}{1moleH_2O}\right)$$

$$n_H = (5.87gH_2O)\left(\frac{mole\ H_2O}{(16.00+2(1.008))gH_2O}\right)\left(\frac{2moleH}{moleH_2O}\right)$$

$$n_H = (5.87gH_2O)\left(\frac{mole\ H_2O}{(18.016gCO_2)}\right)\left(\frac{2moleH}{moleH_2O}\right)$$

$n_C = 0.6517mole$ $\quad n_C = 0.652mole$

Example : The compound that gives fermented grape juice, malt liquor, and vodka their intoxicating properties is ethyl alcohol, which contains the elements carbon, hydrogen, and oxygen. When a sample of ethyl alcohol is burned in air, it is found that 5.00 g ethyl alcohol goes to 9.55 g CO_g plus 5.87g H_2O

What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O

How are we going to get it?
gO in original sample?

$$g_{total} = g_C + g_H + g_O$$

$$5.00g_{total} = 2.61g_C + 0.657g_H + g_O$$

$$g_c = (g_{CO_2})\left(\frac{amugC}{amug_{CO_2}}\right)$$

$$g_c = (9.55g_{CO_2})\left(\frac{12.01gC}{44.01g_{CO_2}}\right) = 2.61g_C$$

3 sig fig

$$g_H = (g_{H_2O})\left(\frac{amugH}{amug_{H_2O}}\right)$$

3 sig fig

$$g_c = (5.87g_{CO_2})\left(\frac{2(1.008)gC}{18.016g_{CO_2}}\right) = 0.657g_C$$

Now know:
mol C 0.217
mol H 0.652
Need to know mol O.

$gO = 5.00 - 2.61 - 0.657$
$gO = 1.733$
$gO = 1.73$

Example : The compound that gives fermented grape juice, malt liquor, and vodka their intoxicating properties is ethyl alcohol, which contains the elements carbon, hydrogen, and oxygen. When a sample of ethyl alcohol is burned in air, it is found that 5.00 g ethyl alcohol goes to 9.55 g CO_g plus 5.87g H_2O

What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O

$$n = \frac{m}{MM} = m\left(\frac{1}{MM}\right)$$

$$5.00g_{total} = 2.61g_C + 0.657g_H + g_O$$

$gO = 5.00 - 2.61 - 0.657$

$gO = 1.73$

$$n_O = (gO)\left(\frac{moleO}{amu\ gO}\right)$$

$$n_H = (1.73gO)\left(\frac{1mole\ O}{(16.00gO)}\right)$$

$n_O = 0.108125mole$

$n_O = 0.108mole$

Example : The compound that gives fermented grape juice, malt liquor, and vodka their intoxicating properties is ethyl alcohol, which contains the elements carbon, hydrogen, and oxygen. When a sample of ethyl alcohol is burned in air, it is found that 5.00 g ethyl alcohol goes to 9.55 g CO_g plus 5.87g H_2O

What is the simplest formula of ethyl alcohol?

5.00g ethyl alcohol
9.55 g CO_2
5.87 g H_2O
simplest formula?

elements C, H, O

molO=0.108
molH=0.652
molC=0.217

$$\frac{0.108 mol_O}{0.108 mol_O} = 1$$

$$\frac{0.652 mol_H}{0.108 mol_O} = 6.037 = 6$$

$$\frac{0.217 mol_C}{0.108 mol_O} = 2.009 = 2$$

C_2H_6O

Sugar of lead (lead acetate) was used from 0 A.D. to 1750s A.D. to “sweeten” ethyl alcohol (wine) and to prevent wine from going bad

One (unproven) theory is that the Roman leaders were poisoned by excessive lead acetate consumption leading to the fall of Rome.

Mass Relations and Stoichiometry

Chemical Formulas ✓

Write reactions

Relate to Mass Ratios and Stoichiometry

Predict
Change in amounts

Consider what happens when one part necessary for the Reaction (recipe) is limiting

Mass Relations In Reactions
Writing and Balancing Chemical Reactions

Lead Hand Side	**Right Hand Side**
Reactants	Products
number atoms A as reactants =	number atoms A as products
number atoms Bas reactants =	number atoms B as products
number atoms C as reactants =	number atoms C as products
. •	•
. •	•
. •	•
Number atoms Z as reactants =	number atoms Z as products

Steps to Balance Reaction Equations

1. Write a “skeleton” equation with molecular formulas of reactants on left, products on right
2. Indicate the physical state of the reactants and products
   - a. (g) for a gas
   - b. (l) for a liquid
   - c. (s) for a solid
   - d. (aq) for an ion or molecule in water (aqueous) solution
3. Chose an element that appears in only one molecular formula on each side of the equation
4. Balance the equation for mass of that element
   - a. placing coefficients **in front** of the molecular formula **NOT by changing subscripts** in the molecular formula
5. Continue for the other elements
6. The best answer is the one which is simplest whole-number coefficients

Example: Lead sulfide

burn in the presence of oxygen.

minium, is formed, Pb_3O_4. The sulfur is converted in the reaction to the gas SO_2.

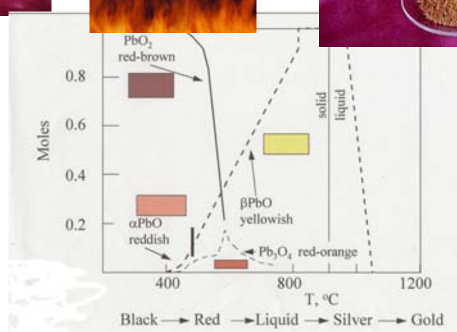
Write a balanced chemical equation for the reaction of lead ore, galena with oxygen gas (O_2) to form minium and SO_2 gas.

PbS Burned in O_2 To make Pb_3O_4 (minium) and SO_2

$$PbS + O_2 \rightarrow Pb_3O_4 + SO_2$$

PbS

Pb_3O_4



1S 1S

$$PbS + O_2 \rightarrow Pb_3O_4 + SO_2$$

1Pb 3Pb

3S 1S

$$3(PbS) + O_2 \rightarrow Pb_3O_4 + SO_2$$

Subscript indicating number Pb within a single molecule

3Pb 3Pb

3S 3S

$$3PbS + O_2 \rightarrow Pb_3O_4 + 3SO_2$$

2O

4O+(3x2)O=10 O

$3PbS + O_2 \rightarrow Pb_3O_4 + 3SO_2$ From previous slide

4O+3x2O=10O

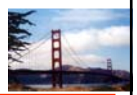
$3PbS + 5O_2 \rightarrow Pb_3O_4 + 3SO_2$

5x2O=10O

4O+3x2O=10O

Be sure to indicate the physical state of the reactants and products

$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$



3 5 1 3

STOICHIOMETRY

Sets up proportionalities

BUT How doe we make use
Of those proportionalities?

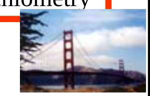
Mass Relations and Stoichiometry

Chemical Formulas ✓

Write reactions ✓

Relate to Mass Ratios and Stoichiometry ✓

Predict
Change in amounts



Consider what happens when one part necessary for the
Reaction (recipe) is limiting

Mass Relations and Stoichiometry

Chemical Formulas

Write reactions

Relate to Mass Ratios and Stoichiometry

Predict
Change in amounts

Consider what happens when one part necessary for the
Reaction (recipe) is limiting

---

2 MAIN Strategies to solving these problems

Step wise

1. **Easy conceptually = series of proportionalities**

1. **Longer time to compute**
2. **Easy to lose track of units**

Will model this one
To begin with

String wise

1. **Not easy conceptually when you are starting out**

1. **Shorter time to compute**
2. **Easy to keep track of units**

BUT will eventually
Only use this method!!!

$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

1. Find moles of SO_2 by Stoichiometry
2. Find grams of SO_2 from those moles

STOICHIOMETRY

$\frac{x}{1.34mol_{O_2}} = \frac{3molSO_{2(g)}}{5molO_{2(g)}}$

$m = nMM$

$x = \left[\frac{3molSO_{2(g)}}{5molO_{2(g)}}\right](1.34mol_{O_2}) = 0.804molSO_{2(g)}$

$gSO_2 = 0.804molSO_2\left[\frac{gSO_2}{molSO_2}\right]$

$gSO_2 = 0.804molSO_2\left[\frac{Samu + 2(Oamu)}{molSO_2}\right]$

$gSO_2 = 0.804molSO_2\left[\frac{(32.07 + 2(16.00))gSO_2}{molSO_2}\right]$

$gSO_2 = 0.804molSO_2\left[\frac{64.07gSO_2}{molSO_2}\right]$

$gSO_2 = 51.51228$

$gSO_2 = 51.5gSO_2$

$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

Alternative Strategy is to fold all calculations together

$x = (1.34mol_{O_2})\left[\frac{3molSO_{2(g)}}{5molO_{2(g)}}\right]\left[\frac{amu_s + 2(amu_{O_2})}{molSO_2}\right]$

$x = (1.34mol_{O_2})\left[\frac{3molSO_{2(g)}}{5molO_{2(g)}}\right]\left[\frac{gSO_2}{molSO_2}\right]$

$x = (1.34mol_{O_2})\left[\frac{3molSO_{2(g)}}{5molO_{2(g)}}\right]\left[\frac{64.07gSO_2}{molSO_2}\right] = 51.51228g = 51.5g$

$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

b) The mass in grams of O_2 required to form 1.000 kg of Pb_3O_4

Stepwise calculations

1. **Find moles of Pb_3O_4 formed**
2. Use Stoichiometry to find moles of O_2
3. Find grams of O_2 from those moles

$m = nMM \qquad n = \frac{m}{MM}$

$molPb_3O_4\ formed = \frac{1kgPb_3O_4\left[\frac{10^3g}{kg}\right]}{\left[\frac{gPb_3O_4}{molPb_3O_4}\right]}$

$molPb_3O_4\ formed = \frac{1kgPb_3O_4\left[\frac{10^3g}{kg}\right]}{\left[\frac{3(207.2) + 4(16.00)gPb_3O_4}{molPb_3O_4}\right]}$

$molPb_3O_4\ formed = \frac{1kgPb_3O_4\left[\frac{10^3g}{kg}\right]}{\left[\frac{685.6gPb_3O_4}{molPb_3O_4}\right]}$

$molPb_3O_4\ formed = 1.458576429 = 1.459$

$molPb_3O_4\ formed = 1.459$

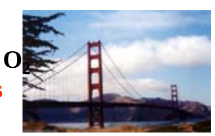
$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

b) The mass in grams of O_2 required to form 1kg of Pb_3O_4

1. Find moles of Pb_3O_4 formed
2. **Use Stoichiometry to find moles of O**
3. **Find grams of O_2 from those moles**



$\frac{x}{1.459molPb_3O_4} = \frac{5molO_2}{molPb_3O_4}$

$x = (1.459)(5molO_2) = 7.295molO_2$

$m = n(MM)$

$x = 7.295molO_2\left[\frac{gO_2}{molO_2}\right]$

$x = 7.295molO_2\left[\frac{32.00gO_2}{molO_2}\right] = 233.4g$

$$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$$

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

b) The mass in grams of O_2 required to form 1kg of Pb_3O_4

Alternative string strategy

$$x = (1kg_{Pb_3O_4})\left[\frac{10^3 g}{kg}\right]\left[\frac{mol_{Pb_3O_4}}{g_{Pb_3O_4}}\right]\left[\frac{5mol_{O_2}}{mol_{Pb_3O_4}}\right]\left[\frac{g_{O_2}}{mol_{O_2}}\right]$$

$$x = (1kg_{Pb_3O_4})\left[\frac{10^3 g}{kg}\right]\left[\frac{mol_{Pb_3O_4}}{685.6g_{Pb_3O_4}}\right]\left[\frac{5mol_{O_2}}{mol_{Pb_3O_4}}\right]\left[\frac{32.00g_{O_2}}{mol_{O_2}}\right]$$

$$x = 233.37g$$

$$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$$

Stepwise method

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

b) The mass in grams of O_2 required to form 1kg of Pb_3O_4

c) The mass in grams of PbS required to react with 6.00 g of O_2

1. Get moles of O_2
2. Use Stoichiometry to get moles of PbS
3. Get grams of PbS

$$m = nMM \qquad n = \frac{m}{MM}$$

$$x = \frac{6.00gO_2}{\left[\frac{32.00gO_2}{molO_2}\right]} = 0.1875molO_2$$

$$\frac{x}{0.1875molO_2} = \frac{3molPbS}{5molO_2}$$

$$x = 0.1125mol$$

$$x = (0.1125molPbS)M_{PbS}$$

$$x = 0.1125molPbS\left[\frac{207.2amu_{Pb} + 32.07amu_S}{molPbS}\right]$$

$$x = 0.1125molPbS\left[\frac{239.27gPbS}{molPbS}\right] = 26.917875g$$

$$x = 26.9g$$

$$3PbS_{(s)} + 5O_{2(g)} \rightarrow Pb_3O_{4(s)} + 3SO_{2(g)}$$

Stringwise

Determine:

a) The mass in grams of SO_2 formed when 1.34 mol of O_2 reacts

b) The mass in grams of O_2 required to form 1kg of Pb_3O_4

c) The mass in grams of PbS required to react with 6.00 g of O_2

$$x = (6.00gO_2)\left[\frac{molO_2}{32.00gO_2}\right]\left[\frac{3molPbS}{5molO_2}\right]\left[\frac{239.27gPbS}{molPbS}\right]$$

$$x = 26.917g$$

$$x = 26.9g$$

Chemical Formulas → Write reactions → Relate to Mass Ratios and Stoichiometry → Predict Change in amounts →

Consider what happens when one part necessary for the Reaction (recipe) is limiting

Rules for Limiting Reagent

1. Calculate the amount of product that would be formed if the first reactant were completely consumed
2. Repeat for the second reactant
3. Choose the smaller of the two amounts. This it the theoretical yield of the product.
4. The reactant that produces the smaller amount of the product is the limiting reagent.
5. The other reagent is in excess, only part of it is consumed.

Limiting Reagents
Liebig's Law of the Limiting (1810-1820 Germany)

I have 1 dozen eggs, 2 packages of chocolate chips, and An entire carton of flour, an entire carton of sugar, a new bottle Of vanilla, and a new box of baking powder. The chocolate chip recipe calls for 2 eggs, 3 cups flour, 1 cup Sugar, 1 package chocolate chips, 1 tbsp vanilla, and 2 Tbsp baking powder. The recipe results in 36 Chocolate chip cookies.

a. What is the **limiting reagent**?

$$1pkgchips + 2eggs + 3cflour + 1csugar + 1tbspvanilla + 2tbsppowder \xrightarrow{heat} 36cookies$$

Chips	1pkg	**2pkg** →
Eggs	2	**12 eggs**
Flour	3c	>3cups
Sugar	1c	>1cup
vanilla	1tbsp	>1tbsp
Powder	2tbsp	>2tbsp
Yield	36 cookies	Yield??

$$\frac{?}{2pkg} = \frac{36cookies}{1pkg} \qquad ? = 2pkg\left[\frac{36cookies}{1pkg}\right] = 72cookies$$

$$\frac{?}{12eggs} = \frac{36cookies}{2eggs} \qquad ? = 12eggs\left[\frac{36cookies}{2eggs}\right] = 192cookie$$

Smallest yield = **72 cookies**
Limiting reagent = **chips**

While I wasn't looking, my son snitched 4 cookies.

$$\%yield = \left[\frac{yield_{experimental}}{yield_{theoretical}}\right]100\%$$

$$\%yield_{cookies} = \left[\frac{72-4}{72}\right]100\% = 94.44444 = 94\%$$

Actual Yield≠Theoretical Yield

(most of the time)

"A" students work
(without solutions manual)
~ 10 problems/night.

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