Unit 3: Quantities in Chemistry Review

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ANSWERS

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Percentage Composition

- Element mass ÷ compound mass x 100%
- E.g. in H_2O, H = 11% (2 g ÷ 18 g x 100%)
- Determining % comp from chemical formula

Assume a 1 mol sample to unlock the PT

Calculate the percentage composition by mass of Cu_2SO_4 (6)

✓ Assume a 1 mol sample

$m_{Cu_2SO_4} = \underset{Cu}{2(63.55)} + \underset{S}{32.07} + \underset{O}{4(16)}$

$= 223.17\,g$

✓ $\%Cu = \frac{m_{Cu}}{m_{Cu_2SO_4}} \times 100 = \frac{127.1}{223.17} \times 100 \doteq 56.95\%\,Cu$ ✓

$\%S = \frac{m_S}{m_{Cu_2SO_4}} \times 100 = \frac{32.07}{223.17} \times 100 \doteq 14.37\%\,S$ ✓

$\%O = \frac{m_O}{m_{Cu_2SO_4}} \times 100 = \frac{64}{223.17} \times 100 \doteq 28.68\%\,O$ ✓

✓ ∴ Cu_2SO_4 is 56.95% Cu, 14.37% S, 28.68% O by mass

What is the % composition of a compound with a mass of 48.72g, if it contains 32.69g Zn and 16.03g of S? (5)

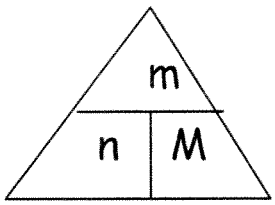
✓ $\%Zn = \frac{m_{Zn}}{m_{compound}} \times 100 = \frac{32.69\,g}{48.72\,g} \times 100 \doteq 67.10\%\,Zn$ ✓

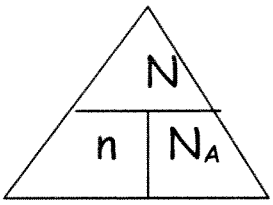
✓ $\%S = \frac{m_S}{m_{compound}} \times 100 = \frac{16.03\,g}{48.72\,g} \times 100 \doteq 32.90\%\,S$ ✓

✓ ∴ the compound is 67.10% Zn & 32.90% S by mass

The mole

- There are 6.02×10^{23} particles in one mole
- Molar mass is calculated from periodic table





Calculate the mass of 2.3 mol of CO_2 (3)

✓ $m = nM$

$= (2.3\,mol)(44.01\,g/mol)$

✓ $\doteq 101.22\,g$

✓ ∴ the mass of 2.3 mol of CO_2 is 101.22 g

Calculate the number of atoms in 11.0g of AgCl (5)

✓ $n_{AgCl} = \frac{m}{M} = \frac{11.0\,g}{143.35\,g/mol} \doteq 0.07674\,mol$ ✓

✓ $N_{atoms} = n N_A \times 2\,\frac{atoms}{molecule} = (0.07674\,mol)(6.02 \times 10^{23})(2) \doteq 9.24 \times 10^{22}$ atoms ✓

✓ ∴ there are 9.24×10^{22} atoms in 11.0 g of AgCl

Empirical and molecular formulae

- Empirical formula is the lowest whole number ratio of atoms in a compound. i.e. CH_2O is the empirical formula for $C_6H_{12}O_6$. A factor of 6 was removed from $C_6H_{12}O_6$ to get CH_2O
- Molecular formula is the actual amount of each atom in the molecule. i.e. $C_6H_{12}O_6$
- Determining empirical formula from % composition **Assume a 100 g sample**
- ** MULTIPLE = molecular formula mass (M_{MF}) / empirical formula mass (M_{EF})

a) What is the empirical formula of a compound that is 15.9% B & 84% F? (6)

✓ Assume a 100g sample

✓ $n_B = \frac{m}{M} = \frac{15.9\,g}{10.81\,g/mol} \doteq 1.471\,mol\,B$ ✓

$n_F = \frac{m}{M} = \frac{84\,g}{19\,g/mol} \doteq 4.421\,mol\,F$ ✓

$\frac{1.471}{1.471} : \frac{4.421}{1.471}$

✓ 1 : 3

✓ ∴ the EF is BF_3

b) If the actual molar mass is 203.43 g/mol calculate the molecular formula. (4) 4

$M_{EF} = \underset{B}{10.81} + \underset{F}{3(19)}$

✓ $= 67.81\,g/mol$

✓ $multiple = \frac{M_{MF}}{M_{EF}} = \frac{203.43}{67.81}$

✓ $= 3$

✓ ∴ the MF is B_3F_9

Hydrate

Find the mass of anhydrous compound, find the mass of water, determine moles of each, divide by smallest

An empty crucible has a mass of 12.770 g. The crucible and hydrate, $CuSO_4 \bullet xH_2O$, have a mass of 13.~~444~~ 173 g. After heating, the crucible and anhydrous salt have a mass of 13.010 g. What is the formula of this hydrate? (9)

$m_{CuSO_4} = m_{after\ heating} - m_{crucible}$
$= 13.010g - 12.770g$
$= 0.24g$

$n_{CuSO_4} = \frac{m}{M}$
$= \frac{0.24g}{159.62g/mol}$
$= 1.504 \times 10^{-3}$ mol

$m_{H_2O} = m_{crucible+hydrate} - m_{after}$
$= 13.173g - 13.010g$
$= 0.~~444~~g\ 0.1626g$

$n_{H_2O} = \frac{m}{M}$
$= \frac{0.444g\ 0.1626g}{18.02g/mol}$
$= 0.~~02464~~$ mol
0.009024 mol

$CuSO_4 : H_2O$
$\frac{0.001504}{0.001504} : \frac{0.009024}{0.001504}$
$1 : 6$

$\therefore$ the hydrate is $CuSO_4 \bullet 6H_2O$

Balancing Chemical Equations

- Balancing equations by inspection, leaving H and - O to the end and O to the very, very end
- H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2 are diatomic gases

Stoichiometry

- 1. Balanced chemical equation
- 2. Convert to moles
- 3. Molar ratio
- 4. Get your answer
- 5. Therefore statement

If 25 g of hydrogen reacts with excess oxygen, how much water is produced? (8)

① $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
m = 25g m = ?

② $n_{H_2} = \frac{m}{M}$
$= \frac{25g}{2.02g/mol}$
$= 12.376$ mol H_2

③ $\frac{2 mol\ H_2}{12.376 mol} = \frac{2 mol\ H_2O}{x}$
$x = 12.376$ mol H_2O

④ $m_{H_2O} = nM$
$= (12.376 mol)(18.02g/mol)$
$= 223.02$ g

⑤ $\therefore$ 223.02g of water is produced.

Limiting reagents

Stoichiometry that requires you to calculate moles of BOTH reactants and set-up 2 MOLAR RATIOS comparing each reactant mol to the same product.

if 20.58 g of O_2 combines with 26 g NH_3 ...

a) What is the limiting reagent? (9)

$5O_{2(g)} + 4NH_{3(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}$
m = 20.58g m = 26g m = ?

$n_{O_2} = \frac{m}{M}$
$= \frac{20.58g}{32g/mol}$
$= 0.643$ mol O_2

$n_{NH_3} = \frac{m}{M}$
$= \frac{26g}{17.03g/mol}$
$= 1.527$ mol

$\frac{5 mol\ O_2}{0.643} = \frac{6 mol\ H_2O}{x}$
$x = 0.772$ mol

$\frac{4 mol\ NH_3}{1.527} = \frac{6 mol\ H}{x}$
$x = 2.291$ mol

$\therefore O_2$ is the limiting reactant

Percentage yields

- Percentage yield = actual/theoretical x100%
- Actual yield is given, theoretical is calculated
- 4 reasons why actual yield falls short

b) What mass of water can theoretically form? (3)

$m_{H_2O} = nM$
$= (0.772 mol)(18.02g/mol)$
$= 13.91g$

$\therefore$ 13.91g of water can theoretically form

c) If 5 g of water is the actual yield, what is the percentage yield? (3)

$\% Yield = \frac{AY}{TY} \times 100$
$= \frac{5g}{13.91g} \times 100$
$= 35.94\%$

$\therefore$ the % yield is 35.94%

(d) What is the mass of the remaining reactant? (7)

$\frac{6 mol\ H_2O}{0.772 mol} = \frac{4 mol\ NH_3}{x}$
$x = 0.515$ mol NH_3 used

$n_{excess} = n_{start} - n_{used}$
$= 1.527 - 0.515$
$= 1.012$ mol used

$m_{NH_3} = nM$
$= (1.012)(17.03)$
$= 17.24g$

$\therefore$ 17.24g of NH_3 remain