CHEM 103
R&R—extra Exam 1 practice :)
7 June 2024
Adapted from a 12 June 2021 document

1. Fill in the missing information.

Symbol	Element	# protons	# neutrons	# electrons	Charge
$^{14}_{6}C$	carbon	6	8	6	0
$^{235}_{92}U$	uranium	92	143	92	0
$^{32}_{16}S^{2-}$	sulfur	16	16	18	-2
$^{137}_{56}Ba^{2+}$	barium	56	81	54	+2
$^{37}_{17}Cl^{-}$	chlorine	17	20	18	-1

2. A mass spectrum tells us that 60.10% of a metal is present as ^{69}M, and 39.90% is present as ^{71}M. The mass values for ^{69}M and ^{71}M are 68.93 amu and 70.92 amu, respectively. What is the average atomic mass of the element? What is the element?

atomic mass = $(.6010)(68.93 \text{ amu}) + (.3990)(70.92 \text{ amu}) = 69.72 \text{ amu}$

Element is Gallium

3. Indium exists as two isotopes. ^{113}In has a mass of 112.9043 amu, and ^{115}In has a mass of 114.9041 amu. The average atomic mass of indium is 114.82 amu. Calculate the percent relative abundance of the two isotopes of indium.

Let x, y be abundance of ^{113}In, ^{115}In respectively.

$x + y = 1$; $(112.9043 \text{ ~~amu~~})x + (114.9041 \text{ ~~amu~~})y = 114.82 \text{ ~~amu~~}$

$x = 1 - y$

$112.9043(1-y) + 114.9041y = 114.82 \Rightarrow \underbrace{(114.9041 - 112.9043)}_{1.9998}y = \underbrace{114.82 - 112.9043}_{1.9157}$

$y = 95.8\% \rightarrow {}^{115}In$

$x = 4.2\% \rightarrow {}^{113}In$

4. Strategies for balancing equations:

   a. Find atoms that are only in one compound on one side; balance those first.

   b. Generally, leave oxygen and hydrogen until the end. They appear many times, and balancing other atoms will often force O and H to become balanced.

   c. Double check after balancing.

$\underline{2}$ Ca + $\underline{2}$ C + $\underline{3}$ $O_2 \rightarrow$ $\underline{2}$ $CaCO_3$

$\underline{2}$ FeS + $\underline{\tfrac{7}{2}}$ $O_2 \rightarrow$ $\underline{1}$ Fe_2O_3 + $\underline{2}$ SO_2

$\underline{1}$ $Mg(OH)_2$ + $\underline{2}$ HCl $\rightarrow$ $\underline{1}$ $MgCl_2$ + $\underline{2}$ H_2O

$\underline{3}$ $CaCl_2$ + $\underline{2}$ $Na_3PO_4 \rightarrow$ $\underline{1}$ $Ca_3(PO_4)_2$ + $\underline{6}$ NaCl

$\underline{1}$ PCl_5 + $\underline{4}$ $H_2O \rightarrow$ $\underline{1}$ H_3PO_4 + $\underline{5}$ HCl

5. Oxidation-Reduction (AKA "Redox")

   a. OIL RIG ➔ <u>o</u>xidation <u>i</u>s <u>l</u>osing (electrons), <u>r</u>eduction <u>i</u>s <u>g</u>aining (electrons).

   b. LEO the lion goes "GER" ➔ <u>L</u>osing <u>E</u>lectrons = <u>O</u>xidation; <u>G</u>aining <u>E</u>lectrons = <u>R</u>eduction.

   c. Something that is reduced is called an *oxidizing agent*. Something that is oxidized is called a *reducing agent*. (What the agent is doing to whatever it reacts with?)

Assign oxidation states to each atom in the following equation. Then state which elements have been reduced/oxidized and list the oxidizing and reducing agents.

["thermite reaction" often used for railway welding!]

Fe_2O_3 (s) + 2 Al (s) $\rightarrow$ Al_2O_3 (s) + 2 Fe (l)

+3 −2   +0   +3 −2   +0

reduced: Fe   OA: Fe_2O_3

oxidized: Al   RA: Al

[cool color change!]

2 MnO_4^- (aq) + 16 H^+ (aq) + 5 $C_2O_4^{2-}$ (aq) $\rightarrow$ 2 Mn^{2+} (aq) + 10 CO_2 (g) + 8 H_2O (l)

+7 −2   +1   +3 −2   +2   +4 −2   +1 −2

reduced: Mn   OA: MnO_4^-

oxidized: C   RA: $C_2O_4^{2-}$

[bad way to make vinegar]

4 CrO_4^{2-} (aq) + 20 H^+ (aq) + 3 CH_3CH_2OH (aq) $\rightarrow$ 4 Cr^{3+} (aq) + 3 CH_3COOH (aq) + 13 H_2O (l)

+6 −2   +1   −3 −1 −2 (+1)   +3   −3 +3 −2 (+1)   +1 −2

reduced: Cr   OA: CrO_4^{2-}

oxidized: C   RA: CH_3CH_2OH

6. Write the molecular, total ionic, and net ionic forms for the following equations:

a. Aqueous acetic acid reacts with aqueous ammonia.

$$CH_3CO_2H\,(aq) + NH_3\,(aq) \rightleftharpoons CH_3CO_2^-\,(aq) + NH_4^+\,(aq)$$

total ionic is same

net ionic is same

b. Aqueous perchloric acid reacts with aqueous lithium hydroxide.

$$HClO_4\,(aq) + LiOH\,(aq) \longrightarrow H_2O\,(l) + LiClO_4\,(aq)$$

total ionic: $H_3O^+\,(aq) + ClO_4^-\,(aq) + Li^+\,(aq) + OH^-\,(aq) \longrightarrow 2H_2O\,(l) + Li^+\,(aq) + ClO_4^-\,(aq)$

net ionic: $H_3O^+\,(aq) + OH^-\,(aq) \longrightarrow 2H_2O\,(l)$

c. Aqueous sodium hydroxide reacts with aqueous phosphoric acid.

$$NaOH\,(aq) + H_3PO_4\,(aq) \longrightarrow H_2O\,(l) + NaH_2PO_4\,(aq)$$

total ionic: $Na^+\,(aq) + OH^-\,(aq) + H_3PO_4\,(aq) \longrightarrow H_2O\,(l) + Na^+\,(aq) + H_2PO_4^{3-}\,(aq)$

net ionic: $OH^-\,(aq) + H_3PO_4\,(aq) \longrightarrow H_2O\,(l) + H_2PO_4^{3-}\,(aq)$

7. Predict the products and balance the following reactions:

a. <u>2</u> KCl (aq) + <u>1</u> $Pb(CH_3CO_2)_2$ (aq) → $PbCl_2\,(s) + 2\,KCH_3CO_2\,(aq)$

b. <u>2</u> $AgNO_3$ (aq) + <u>1</u> $MgBr_2$ (aq) → $2AgBr\,(s) + Mg(NO_3)_2\,(aq)$

8. Sodium hydroxide reacts with sulfuric acid to give sodium sulfate and water. If 17.80 g NaOH is mixed with 15.40 g H_2SO_4, $2NaOH + H_2SO_4 \rightarrow 2H_2O + Na_2SO_4$

a. How many grams of Na_2SO_4 can be formed?

$$17.80\text{ g NaOH} \cdot \frac{\text{mol NaOH}}{39.997\text{ g NaOH}} = 0.4450\text{ mol NaOH}$$

$$15.40\text{ g } H_2SO_4 \cdot \frac{\text{mol } H_2SO_4}{98.078\text{ g } H_2SO_4} = 0.1570\text{ mol } H_2SO_4$$

← limiting reactant

$$0.1570\text{ mol } Na_2SO_4 \cdot \frac{142.042\text{ g } Na_2SO_4}{\text{mol}} = 22.30\text{ g } Na_2SO_4$$

b. How many grams of excess reactant remains unreacted?

Remaining: $(0.4450\text{ mol NaOH} - 2 \cdot 0.1570\text{ mol NaOH}) \cdot \frac{39.997\text{ g NaOH}}{\text{mol NaOH}}$

$= 5.240\text{ g NaOH}$

c. If the actual yield of Na_2SO_4 was 15.00 g, what is the percent yield of Na_2SO_4?

$$\frac{15.00\text{ g } Na_2SO_4}{22.30\text{ g } Na_2SO_4} = 67.26\%\text{ yield}$$

9. The Space Shuttle environmental system handles excess CO_2 (which the astronauts breathe out—it is 4% of exhaled air by mass) by reacting it with LiOH pellets to form lithium carbonate and water. If there are seven astronauts on board the shuttle and each exhales 20 liters of air per minute, how long could clean air be generated if there were 25 kg of LiOH pellets available for each shuttle mission? Assume the density of air is 0.0010 g/mL.

$2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O.$

$$25000\text{ g LiOH} \cdot \frac{\text{mol LiOH}}{23.948\text{ g LiOH}} \cdot \frac{\text{mol } CO_2}{2\text{ mol LiOH}} \cdot \frac{44.01\text{ g } CO_2}{\text{mol } CO_2} \cdot \frac{100\text{ g air}}{4\text{ g } CO_2} \cdot \frac{\text{mL}}{0.0010\text{ g}} \cdot \frac{\text{L}}{1000\text{ mL}}$$

$= 574291\text{ L air}$

$$574291\text{ L air} \cdot \frac{\text{min}}{140\text{ L air}} = 4100\text{ min (approx. 68 hours)}$$

10. What mass of $Fe(OH)_3$ is produced when 35.0 mL of 0.250 M $Fe(NO_3)_3$ solution is mixed with 55.0 mL of 0.180 M KOH solution?

$$(35.0\ mL)(0.250\ M\ Fe(NO_3)_3) \cdot \frac{mol\ Fe^{3+}}{mol\ Fe(NO_3)_3} = 8.75\ mmol\ Fe^{3+}$$

$$(55.0\ mL)(0.180\ M\ KOH) \cdot \frac{mol\ OH^-}{mol\ KOH} = 9.90\ mmol\ OH^-$$] limiting reactant

$$9.90\ mmol\ OH^- \cdot \frac{mol\ Fe(OH)_3}{3\ mol\ OH^-} \cdot \frac{106.866\ g\ Fe(OH)_3}{mol\ Fe(OH)_3} = 0.353\ g\ Fe(OH)_3$$

11. You want to determine the molar mass of an acid. The acid contains one acidic hydrogen per molecule. You weigh out a 2.879 g sample of the pure acid and dissolve it, along with 3 drops of phenolphthalein indicator, in distilled water. You titrate the sample with 0.1704 M NaOH. The pink endpoint is reached after addition of 42.55 mL of base. Calculate the molar mass of the acid.

$$(42.55\ mL)(0.1704\ M\ NaOH) \cdot \frac{mol\ acid}{mol\ NaOH} = 7.25\underline{0}5\ mmol\ acid$$

$$\frac{2.879\ g}{7.25\underline{0}5 \times 10^{-3}\ mol} = 397.1\ \frac{g}{mol}$$

12. Redox titration strategy:

i. Balance the redox equation (recommended: half-reaction method)
ii. Determine moles of titrant
iii. Use balanced redox equation to determine moles of unknown
iv. Convert moles of unknown to whichever quantity is requested

A 0.0483 M $KMnO_4$ solution was used to titrate a solution containing 0.8329 g impure calcium oxalate, CaC_2O_4. If 30.25 mL of the $KMnO_4$ solution was required to reach the titration endpoint, calculate the percent purity of the CaC_2O_4. This reaction takes place in acidic solution.

i)

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

$$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-$$

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

spectator cations not shown

ii) $(30.25 \text{ mL})(0.0483 \text{ M } MnO_4^-) = 1.461 \text{ mmol } MnO_4^-$

iii, iv) $1.461 \text{ mmol } MnO_4^- \cdot \dfrac{5 \text{ mol } CaC_2O_4}{2 \text{ mol } MnO_4^-} \cdot \dfrac{128.10 \text{ g } CaC_2O_4}{\text{mol } CaC_2O_4} = 467.9 \text{ mg } CaC_2O_4$

$$\frac{467.9 \text{ mg } CaC_2O_4}{832.9 \text{ mg sample}} = 56.2\% \; CaC_2O_4$$