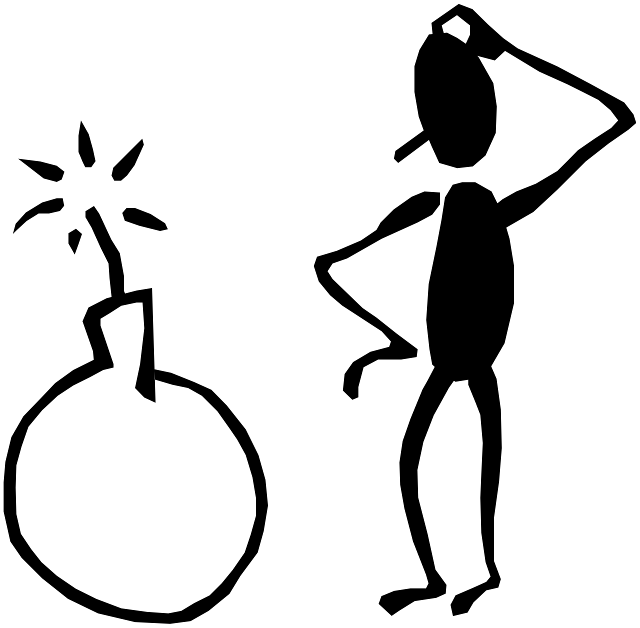
Name: KEY

Chemistry 20

Worksheets



Worksheet 1.1: Atomic Structure

1. Complete the following table. Using symbols, provide an example of each category using the element provided. For the average atom assume that the mass number is the atomic mass rounded off. The first one is done. (8 marks) (1/2 mark off for each mistake in each row).

	Average Atom	**Monoatomic Polyatomic or diatomic element**	**Most common simple Ion**	**Complex or polyatomic Ion**	**Isotope of the average**	**Ionic compound**	**Molecular compound**	**Acid compound**
chromium	^{52}Cr	Cr	Cr^{3+}	CrO_4^{2-}	^{53}Cr	Cr_2O_3	NONE	NONE
sulphur	^{32}S	$S_{8(s)}$	S^{2-}	SO_4^{2-} or SO_3^{2-}	^{33}S	$Na_2S_{(aq)}$	$SO_{2(g)}$	$H_2SO_{4(aq)}$ $H_2SO_{3(aq)}$
nitrogen	^{14}N	$N_{2(g)}$	N^{3-}	NO_3^- or NO_2^-	^{13}N	$Na_3N_{(aq)}$	$NO_{2(g)}$	$HNO_{3(aq)}$ $HNO_{2(aq)}$

2. Complete the following table. Note that the mass number can change for isotopes. If there is not a noble gas with the same # of electrons, than put NONE. The first one is done.(6 marks) (1/2 mark off for each mistake in each row)

Atom or Ion name	**Atom or ion symbol**	**Atomic number**	**Mass number**	**Protons**	**Electrons**	**Neutrons**	**Noble Gas with same # of electrons**
sodium ion	$^{23}Na^+$	11	23	11	10	12	neon
aluminum atom	^{28}Al	**13**	28	**13**	**13**	**15**	**neon**
chloride ion	Cl^{1-}	**17**	34	17	18	**17**	**argon**

Worksheet 1.2: Compounds

Complete the following table (Assume water is used with ionic compounds): (16 marks)

I = M (NH_4) + N M = non metals A = H (acid) pg 8/9 in databook	chemical formula(add states)	chemical name
Ionic	$K_2SO_{3(aq)}$	Metal name + polyatomic name **potassium sulfite**
ACID	$H_2SO_{4(aq)}$	sulphuric acid
IONIC	$Na_2S_2O_3 \bullet 1\ H_2O_{(s)}$	**sodium thiosulfate monohydrate**
MOLECULAR	$C_2H_5OH(l)$	ethanol
IONIC	$Pb^{2+/4+}(SO_4)^{2-}{}_{2\,(aq)}$ 4+ = 4-	**lead (IV) sulphate**
MOLECULAR	$P_5O_{10\,(g)}$	**Pentaphosphorus dexaoxide**
MOLECULAR	**$C_{12}H_{22}O_{11}$ (s)**	sucrose
IONIC	**Na_2SIO_3(aq)**	sodium silicate
MOLECULAR	NH_3(g)	Ammonia is not ammonium

MOLECULAR (NOT AN ACID)	$H_2O_{2\,(l)}$	**Hydrogen peroxide**
MOLECULAR	$SO_{3\,(g)}$ does not equal $SO_3{}^{2-}{}_{(aq)}$	**Sulfur trioxide (NOT sulfite)**
IONIC (NH4+ is an ion)	$(NH_4)_3PO_{4\,(aq)}$	ammonium phosphate
IONIC	**Cu^{2+} SO_4^{2-}** **$CuSO_4$* $5H_2O(s)$**	copper (II) sulphate pentahydrate
MOLECULAR (MEMORIZED)	**$C_3H_8(g)$**	propane
ACID	**$CH_3COOH(aq)$**	ethanoic acid
MOLECULAR	$O_{3\,(g)}$	**OZONE**
MOLECULAR	$HOH_{\,(g,l,s)}$	**water**

Worksheet 1.3: Reactions

Complete the following reactions, identify the reaction type and balance the equation.(3 marks each; 15 marks total)

1) mercury (II) oxide is broken down into its elements by heating.

Hg^{2+} O^{2-} (Always balance the charges on IONIC compounds)

2 $HgO_{(s)}$ → 2 $Hg_{(l)}$ + $O_{2(g)}$ Decomposition

2) a nickel strip is placed in a gold (III) sulf**ate** solution

COMMON MISTAKES Ni^{2+} (aq) + Au_3S_8 →

$Ni_{(s)}$ + $Au_2(SO_4)_{3(aq)}$ → $Au_{(s)}$ + (Ni $^{2+/3+}$SO4 $^{2-}$) $NiSO_{4(aq)}$
3 Ni(s) + $Au_2(SO_4)_{3(aq)}$ → 2 Au(s) + 3 $NiSO_4$(aq) single replacement

3) phosphoric acid reacts with iron (III) oxide.

2 $H_3PO_{4(aq)}$ + $Fe_2O_{3(s)}$ → 2 $FePO_{4\,(s)}$ + 3 $H_2O_{(l)}$ Double Replacement

H = ~~3~~ 6	**H =2 x 2**
O = 3	**0 = ~~1~~ 3**
PO_4 = 1 x 2	**PO_4 = ~~1~~ 2**
Fe = 2	**Fe = 1 x 2**

4) butane is burned in air (Balance C's first, H's second and O's last)

$C_4H_{10(g)}$ + 6.5 $O_{2(g)}$ → 4$CO_{2(g)}$ +5 $H_2O_{(g)}$
2? = 8 + 5; ? = 6.5

OR 2 $C_4H_{10(g)}$ + 13 $O_{2(g)}$ → 8$CO_{2(g)}$ +10 $H_2O_{(g)}$
Another Combustion question for practice
DECANE: $C_{10}H_{22(l)}$ + 15.5 $O_{2(g)}$ → 10$CO_{2(g)}$ +11 $H_2O_{(g)}$

5) sulfur combines with oxygen to from sulfur trioxide

$S_{8(s)}$ + 12 $O_{2(g)}$ → 8$SO_{3(g)}$ Formation

(NOTE: Sulfur is a polyatomic element)

Worksheet 1.4: Mole Problems

1. MOLAR MASS QUESTIONS

   a. What is the molar mass of chlorine gas?

   Cl_2 Cl x 2 = 35.45 x 2 = 70.90 g/mol

   b. What is the molar mass of hydrogen peroxide?

   H_2O_2 Hx 2 = 1.01 x 2 = 2.02
   O x2 = 16.00 x 2 = 32.00
   Total = 34.02 g/mol

   c. What is the molar mass of lead (II) nitrate?

   Pb $(NO_3)_2$ Pb x1 = 207.2
   N x 2 = 14.01 x 2 = 28.02
   O x 6 = 16.00 x 6 = 96.00
   TOTAL = 231.22 g/mol

2. PARTICLE(Formula Units/Molecules) TO MOLE CALCULATIONS:

   a. How many moles in 6.55×10^{19} atoms of zinc?

Step 1) n=?; p = 6.55E19 atoms; P = 6.02E23 atoms/mol
Step 2) n = p/P
Step 3) n = 6.55E19 atoms / 6.02E23 atoms/mol
Step 4) n = 0.0001088039… mol; 0.000109 mol or 1.09×10^{-4} mol or 0.109 mmol or 109 umol

   b. How many formula units in 3.99 mol of potassium carbonate?

Step 1) p=?; n = 3.99mol; P = 6.02 E23 formula units/mol
Step 2) p = n x P
Step 3) p = 3.99mol x 6.02E23 formula units/mol
Step 4) p = 2.40198 E24 formula units; 2.40E24 formula units or $2.40 X10^{24}$ formula units

   c. How many molecules in 2.00 mol of sulphur dioxide?

Step 1 – 3) p=nP; p=2.00 mol x 6.02E23 molecules/mol
Step 4) p= 1.20E24 molecules of sulphur dioxide

   d. How many moles in 4.5×10^{24} atoms of chlorine?

Steps 1-3) n=p/P; p=4.5E24 atoms / 6.02E23 atoms/mol
Step 4) n= 7.5 mol of chlorine

3. MASS TO MOLE CALCULATIONS:

   a. How many moles in 30.6 g of copper?

Step 1) n=?; m = 30.6g; M_{Cu} = 63.55g/mol
Step 2) n = m/M
Step 3) n = 30.6g/63.55g/mol
Step 4) n = 0.481510… mol; 0.482 mol or 482 mmol (3 significant digits; divide by E-3 to get mmol)

   b. What is the mass of 2.3 mol of carbon dioxide?

Step 1) m=?; n = 2.3mol; M_{CO2} = 44.01g/mol
Step 2) m = nM
Step 3) n = 2.3mol x 44.01g/mol
Step 4) n = 101.22… g; 1.0×10^2 g or 0.10 kg

C = 12.01
O_2=32.00
M = 44.01g/mol

   c. Determine the mass in 56.3 mmol of ethanol?

Step 1) m=?; n = 56.3mmol; M_{C2H5OH} = 46.08g/mol
Step 2) m = nM
Step 3) n = 56.3E-3mol / 46.08 g/mol
Step 4) n = 0.001221… g; 0.00122g or 1.22 mg

C_2=24.02
H_6= 6.06
O =16.00
M=46.08g/mol

   d. How many moles in 56.6 kg of iron (II) oxide ore?

Step 1) n=?; m = 30.6g; M_{Cu} = 63.55g/mol
Step 2) n = m/M
Step 3) n = 30.6g/63.55g/mol
Step 4) n = 0.481510… mol; 0.482 mol or 482 mmol

4. VOLUME TO MOLE CALCULATIONS:

a. Determine the number of moles in 33.6 L of methane at STP?

Step 1) n=?; v = 33.6L; V = 22.4L/mol
Step 2) n = v/V
Step 3) n = 33.6g/22.4L/mol
Step 4) n = 1.50 mol (3 significant digits)

b. What volume of gas would be present in 0.955 mol at SATP?

Step 1) v=?; n = 0.955 mol; V = 22.4L/mol
Step 2) v =nV
Step 3)v = 0.955mol x 24.8L/mol (v = 0.955mol x 22.4 L/mol (STP))
Step 4) v = 23.684; 23.7 L of gas at SATP; (v = 21.392 L; 21.4 L of gas at STP)

c. How many moles in 100 mL of carbon dioxide at SATP?

Step 1) n=?; v = 100mL OR 0.100 L; V = 24.8L/mol
Step 2) n = v/V
Step 3) n = 0.100 L / 24.8 L/mol
Step 4) n = 0.004032258… mol; 0.00403 mol or 4.03 x 10^{-3} mol or 4.03 mmol

d. What volume of nitrogen monoxide would be present in 2.7 mol if the temperature is 25C and the pressure is 100 kPa?

Step 1) v=?; n = 2.7 mol; V = 24.8L/mol (SATP conditions)
Step 2) v = nV
Step 3) v = 2.7 mol x 24.8L/mol
Step 4) v = 66.96 L; 67 L (2 significant digits)

5. What is the mass of 2.3 mol of carbon dioxide at ~~STP~~?

Step 1) n=?; m = 30.6g; M = C = 12.01 x 1 = 12.01
O = 16.00 x 2 = 32.00
TOTAL = 48.01g/mol
Step 2) m = nM
Step 3) m = 2.3mol x 48.01g/mol
Step 4) m =110.423 g; 1.1 x10^{2} g or 0.11 kg (divide by E3 to change to kmol)
NOTE: You have to change to scientific notation since you need 2 sig digs and 100 has 3.

Worksheet 1.5: More difficult mole problems

1. How many atoms of **copper** are in 0.088 mol of copper (I) oxide?

   p=nP; p=0.088 mol x 6.02E23 molecules/mol

   p= 5.2976E22 molecules of Cu_2O

   Cu_2O; p_{cu}= 2 x = 1.059E23; 1.1E23 atoms of copper

2. How many mol of **magnesium ions** are in 1.00 x 10^{20} formula units of magnesium nitride?

   n=p; n=1.00E20 formula units ; n= 1.66 x10^{-4} mol or 0.166 mmol

   P 6.02E23 formula units/mol

   NOT DONE YET….

   Mg_3N_2; n_{Mg}= 3 x 0.166 mmol = 0.498 mmol

3. What is the mass of 14.6 L of carbon monoxide at STP?

C = 12.01 n=v/V; n=14.6L/22.4L/mol; n=0.651785714… mol(don't round)

O = 16.00 m=nM; m=0.651785714…mol x 28.01g/mol; m= 18.256… g; 18.3g

28.01g/mol

4. How many atoms of xenon are in 15 L at SATP?

   n=v/V; n=15L/24.8L/mol; n = 0.6048387…mol

   p=nP; p= 0.6048387…mol x6.02E23 atoms/mol; p=3.6411…E23

   p = 3.6 E 23 atoms

5. How many moles of **carbon and oxygen** are in 6.02 x 10^{23} molecules of carbon dioxide?

   n=p; n=6.02E23 formula units ; n= 1.00 mol

   P 6.02E23 formula units/mol

   NOT DONE YET….

   CO_2; n_C = 1 x 1.00 = 1.00 mol of carbon; n_O = 2 x 1.00 = 2.00 mol of oxygen

6. When studying reactions what unit are most quantities converted into? (HINT: What do the coefficients in front of a balanced equation represent?)

   Most quantities are converted into moles. **The coefficients represent moles**

7. What are the temperature, pressure and molar volume of a gas at STP?

   T = OC (273.15K); P=101.325 kPa; V=22.4 L/mol

8. What are the temperature, pressure and molar volume of a gas at SATP?

   T= 25 C (298.15 K); P = 100 kPa; V = 24.8 L/mol

Worksheet 3.1: Mole to Mole Stoichiometry

Directions: Write balanced equations with states. Solve the problem. Assume water is available.

1. Liquid water decomposes into its elements. **How many moles of hydrogen gas** are produced if 0.500 mol of water is used?

G R

step 1) $2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

0.500 mol ?

step 3) $$0.500 \text{ mol of } H_2O_{(g} \times \frac{2 \text{ mol of } H_{2(g)}}{2 \text{ mol of } H_2O_{(g)}} = 0.500 \text{ mol of } H_2\ (g)$$

2. Sulphur reacts with barium oxide. **How many moles of sulphur** are needed if 2.00 mol of barium oxide is used?

R G

1) $1\ S_8\ (s) + 8\ BaO\ (s) \rightarrow 4\ O_2(g) + 8\ BaS\ (s)$

? 2.00 mol

3) $$2.00 \text{ mol of } BaO_{(s)} \times \frac{1 \text{ mol of } S_{8(s)}}{8 \text{ mol of } BaO_{(s)}} = 0.250 \text{ mol of } S_{8(s)}$$

3. Methane gas burns. **How many moles of oxygen** gas are needed to completely burn 3.00 mol of methane?

G R

1) $1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$

3.00 mol ?

3) $$3.00 \text{mol of } CH_{4(g)} \times \frac{2 \text{ mol of } O_{2(g)}}{1 \text{ mol of } CH_{4\ (g)}} = 6.00 \text{ moles of } O_{2(g)}$$

4. Sodium and phosphorus react. **How many moles of phosphorus** are needed if 0.600 mol of sodium metal is used?

G **R**

1) $12Na_{(s)} + 1\ P_{4(s)} \rightarrow 4Na_3P_{(aq)}$

0.600 mol ?

3) $$0.600 \text{ mol of } Na_{(s)} \times \frac{1 \text{ mole of } P_{4(s)}}{12 \text{ moles of } Na_{(s)}} = 0.0500 \text{ moles of } P_4(s)$$

5. Magnesium phosphate reacts with lithium carbonate. **How many moles of lithium carbonate** are needed when 1.50 mol of magnesium phosphate is used?

G **R**

1) $1\ Mg_3(PO_4)_{2(s)} + 3Li_2CO_{3(aq)} \rightarrow 3MgCO_{3(s)} + 2Li_3PO_{4(aq)}$

1.50 mol ?

3) $$1.50 \text{ mol of } Mg_3(PO_4)_{2(s)} \times \frac{3 \text{ mol of } Li_2CO_{3(aq)}}{1 \text{ mol of } Mg_3(PO_4)_{2(s)}} = 4.50 \text{ mol of } Li_2CO_{3(aq)}$$

6. Sulphur dioxide decomposes. How many moles of sulphur dioxide are needed to produce 0.30 mol of sulphur?

R G

1) $8SO_{2(g)} \rightarrow 1\ S_{8(s)} + 8O_{2(g)}$

3) $$\frac{0.30 \text{ mol of } S_{8(s)} \times 8 \text{ mol of } SO_{2(g)}}{1 \text{ mol of } S_{8(s)}} = 2.4 \text{ mol of Sulphur dioxide}$$

7. Magnesium chloride reacts with sodium. How many moles of sodium are needed to react with 0.0250 mol of magnesium chloride?

G R

1) $1\ MgCl_{2(aq)} + 2Na_{(s)} \rightarrow Mg_{(s)} + 2NaCl_{(aq)}$

3) $$\frac{0.0250 \text{ mol } MgCl_{2(aq)} \text{ of } \times 2 \text{ mol of } Na_{(s)}}{1 \text{ mol of } MgCl_{2(aq)}} = 0.0500 \text{ mol of } Na_{(s)}\ (5.00 \times 10^{-2} \text{ mol})$$

8. Iron (II) phosphate reacts with tin (IV) nitride. How many moles of tin (IV) nitride are needed to produce 0.500 mol of iron (II) nitride?

R G

1) $2\ Fe_3(PO_4)_{2(s)} + 1\ Sn_3N_{2(s)} \rightarrow 2Fe_3N_{2(s)} + Sn_3(PO_4)_{4(s)}$

3) $$\frac{0.500 \text{ mol of } Fe_3N_{2(s)} \times 1 \text{ mol of } Sn_3N_{2(s)}}{2 \text{ mol of } Fe_3N_{2(s)}} = 0.250 \text{ mol of tin (IV) phosphate}$$

9. Gasoline ($C_8H_{18(l)}$) is burned. How many moles of carbon dioxide are produced when 3.00 mol of gasoline is reacted?

G R

2 25 16 18

1) $1\ C_8H_{18(s)} + 25/2\ O_{2(g)} \rightarrow 8CO_{2(g)} + 9H_2O_{(g)}$

3) $$\frac{3.00 \text{ mol of } C_8H_{18(l)} \times 8\ (16) \text{ mol of } CO_{2(g)}}{1\ (2) \text{mol of } C_8H_{18(l)}} = 24.0 \text{ mol of carbon dioxide.}$$

10. Chlorine reacts with potassium bromide. How many moles of chlorine would be needed to completely use up 25 mol of potassium bromide?

R G

1) $1\ Cl_{2(g)} + 2KBr_{(aq)} \rightarrow 2\ KBr_{(aq)} + Br_{2(l)}$

3) $$\frac{25 \text{ mol of } KBr_{(aq)} \times 1 \text{ mol of } Cl_{2\ (g)}}{2 \text{ mol of } KBr_{(aq)}} = 13 \text{ mol of chlorine}$$

Worksheet 3.2: Mole to Quantity Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. When 6.5 mol of solid potassium chlorate breaks into solid potassium chloride and oxygen gas, what mass of solid potassium chloride is produced?

G R

1) $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

6.5 mol ?

UNIT ANALYSIS OR LINEAR METHOD

$$n = 6.5mol \times \frac{2\ mol\ of\ KCl_{(s)}}{2\ mol\ of\ KClO_{(s)}} \times \frac{74.55\ g\ of\ KCl_{(s)}}{1\ mol\ of\ KCl_{(s)}} = 484\ g = 4.8 \times 10^{2} g\ of\ KCl_{(s)}$$

STEP BY STEP METHOD

2) no conversion

3) mol ratio: $n_R = n_G \times R/G$

$6.5\ \cancel{mol\ of\ KClO_{3(s)}} \times 2mol\ of\ KCl_{(s)}\ /2\ \cancel{mol\ of\ KClO_{3(s)}} = 6.5\ moles\ of\ KCl_{(s)}$

4) m=nM $m=74.55\ g/\cancel{mol} \times 6.5\ \cancel{mol} = 484g = 4.8 \times 10^{2}\ g\ of\ KCl_{(s)}$

2. When 5.00 mol of methane burns, what volume of carbon dioxide at STP, will be produced?

G R

1) $1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow 1\ CO_{2(g)} + 2H_2O_{(g)}$

UNIT ANALYSIS OR LINEAR METHOD:

$$5.00\ mol\ of\ CH_4 \times \frac{1\ mol\ of\ CO_2}{1\ mol\ of\ CH_4} \times \frac{22.4\ L\ of\ CO_2}{1\ mol\ of\ CO_2} = 112\ L\ of\ CO_2$$

STEP BY STEP METHOD: 2) no conversion

3) $n_R = n_G \times R/G = 5.00\ mol\ of\ CH_4 \times 1mol\ of\ CO_2\ /1mol\ of\ CH_4 = 5.00\ mol\ of\ CO_2$

4) v = nV $v = 5.00\ mol\ of\ CO_2 \times 22.4L/mol = 112\ L\ of\ CO_2$

3. How many particles of hydrochloric acid is needed to neutralize 2.50 mol of calcium hydroxide?

R G

1) $2HCl_{(aq)} + 1Ca(OH)_{2(s)} \rightarrow 2H_2O_{(g)} + CaCl_{2(aq)}$

? 2.5 mol

UNIT ANALYSIS OR **LINEAR METHOD:**

$$n = 2.5\ mol\ of\ Ca(OH)_{2(s)} \times \frac{2\ mol\ of\ HCl_{(aq)}}{1\ mol\ of\ Ca(OH)_{2(s)}} \times \frac{6.02 \times 10\ 23\ particles\ of\ HCl_{(aq)}}{1\ mol\ of\ HCl_{(aq)}} = 3.01\ E\ 24\ particles$$

STEP BY STEP:

2) no conversion

3) **$n_R = n_G \times R/G = \frac{2.5\ mol\ of\ Ca(OH)_{2(s)} \times 2\ mol\ of\ HCl_{(aq)}}{1\ mol\ of\ Ca(OH)_{2(s)}}$**

n=5.0 mol

***4) p*=nxP *p*= $6.02 \times 10^{23} \times 5.0\ mol = 3.01\ E\ 24$ or 3.01×10^{24} particles of $HCl_{(aq)}$**

4. When 5.25 mol of butane ($C_4H_{10(l)}$) burns, what volume of water vapour will be produced at SATP?

G R

1) $1\ C_4H_{10}(l) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$

UNIT ANALYSIS OR LINEAR METHOD:

$$5.25\ mol\ of\ C_4H_{10(l)} \times \frac{5\ mol\ of\ H_2O_{(g)}}{1\ mol\ of\ C_4H_{10(l)}} \times \frac{24.8\ L\ of\ H_2O_{(g)}}{1\ mol\ of\ H_2O_{(g)}} = 651\ L\ of\ H2O$$

STEP BY STEP METHOD: 2) no conversion

3) $n_R = n_G \times R/G = 5.25\ mol\ of\ C_4H_{10(l)} \times 5mol\ of\ H_2O_{(g)}/1mol\ of\ C_4H_{10(l)} = 16.25\ mol\ of\ H_2O_{(g)}$

4) v = nV $v = 16.25\ mol\ of\ H_2O \times 24.8L/mol = 651\ L$ of water

5. When excess silver reacts with 3.45 mol of zinc phosphate, what mass of silver phosphate would be produced?

G R

1) $6Ag_{(s)} + 1Zn_3(PO_4)_{2(s)} \rightarrow 2Ag_3(PO_4)_{(s)} + 3Zn_{(s)}$

3.45 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$$3.45 \text{ mol of } Zn_3(PO_4)_2 \times \frac{2 \text{ mol of } 2Ag_3PO_4}{1 \text{ mol of } Zn_3(PO_4)_2} \times \frac{418.58 \text{ g of } Ag_3PO_4}{1 \text{ mol of } Ag_3PO_4} = 2888 \text{ g} = 2.89 \text{ kg}$$

STEP BY STEP METHOD: 2) no conversion

3) $n_R = n_G \times R/G = 3.45 \text{ mol of } Zn_3(PO_4)_2 \times \frac{2 \text{ mol of } 2Ag_3PO_4}{1 \text{ mol of } Zn_3(PO_4)_2} = 6.90 \text{ mol}$

4) $m = Mn = (418.58 \text{ g/mol})(6.90 \text{ mol}) = 2888 \text{ g} = 2.89 \times 10^3 \text{ g or } 2.89 \text{ kg}$

6. When 3.00 mol of iron (II) hydroxide reacts with cobalt (II) phosphate, what mass of cobalt (II) phosphate is needed? G R

1) $3\ Fe(OH)_{2(aq)} + Co_3(PO_4)_{2(aq)} \rightarrow 3\ Co(OH)_{2(s)} + Fe_3(PO_4)_{2(aq)}$

3.00 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$$3.00 \text{ mol of } Fe(OH)_{2(aq)} \times \frac{3 \text{ mol of } Co(OH)_{2(s)}}{3 \text{ mol of } Fe(OH)_{2(aq)}} \times \frac{552.55 \text{ g of } Co_3(PO_4)_{2(s)}}{1 \text{ mol of } Co3(PO4)_{2(s)}} = 278.85 = 279 \text{ g of } Co(OH)_2$$

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 3.00 \text{ mol of } Fe(OH)_{2(aq)} \times \frac{3 \text{ mol of } Co(OH)_{2(s)}}{3 \text{ mol of } Fe(OH)_{2(aq)}} = 3.00 \text{ mol of } Co(OH)_{2(s)}$

4) $m = Mn = (92.95 \text{ g/mol})(3.00 \text{ mol}) = 278.85 = 279 \text{ g of } Co(OH)_2$

7. In a neutralization reaction, 4.56 mol of sodium hydroxide neutralizes the sulphuric acid. What mass of water is produced? G R

1) $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(g)} + Na_2SO_{4(aq)}$

4.56 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$$4.56 \text{ mol of } NaOH_{(aq)} \times \frac{2 \text{ mol of } H_2O_{(g)}}{2 \text{ mol of } NaOH_{(aq)}} \times \frac{18.02 \text{ g of } H_2O_{(g)}}{1 \text{ mol of } H_2O_{(g)}} = 8.22 \times 10^1 \text{ g of water}$$

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 4.56 \text{ mol of } NaOH \times \frac{2 \text{ mol of } H_2O}{2 \text{ mol of } NaOH} = 4.56 \text{ mol of } H_2O$

4) $m = Mn = (18.02 \text{ g/mol})(4.56 \text{ mol}) = 8.22 \times 10^1 \text{ g of water}$

8. Hydrogen and 2.5 mol of nitrogen react to form ammonia. How many moles of ammonia will be produced at STP? SATP? G R

1) $3\ H_{2(g)} + 1\ N_{2(g)} \rightarrow 2\ NH_{3(g)}$

UNIT ANALYSIS OR LINEAR METHOD **STP** **SATP**

$$2.5 \text{ mol of } N_{2(g)} \times \frac{2 \text{ mol of } NH_{3(g)}}{1 \text{ mol of } N_{2(g)}} \times \frac{22.4L\ (24.8\ L) \text{ of } NH_{3(g)}}{1 \text{ mol of } NH_{3(g)}} = (112)1.1E2 \text{ L of } N_{2(g)};\ (124)1.2E2 \text{ L of } N_{2(g)}$$

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 2.5 \text{ mol of } N_2 \times \frac{2 \text{ mol of } H_2O}{1 \text{ mol of } NaOH} = 5.00 \text{ mol of } N_2$

4) $v = nV = (5.00\text{mol})(22.4\text{L/mol}) = 1.1E2 \text{ L of } N_2$ **STP**; $v = nV = (5.00\text{mol})(24.8\text{L/mol}) = 1.2E2\text{L of } N_2$ **SATP**

Worksheet 3.3: Quantity to Mole Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. How many moles of iron (III) oxide is produced when 5.6 g of iron burns with oxygen gas?

G R

1) **2 $Fe_{(s)}$ + 3/2 $O_{2(g)}$ $\rightarrow$ 1$Fe_2O_{3(s)}$**

5.6 g ?

UNIT ANALYSIS OR LINEAR METHOD

5.6 g of $Fe_{(s)}$ x 1 mol of $Fe_{(s)}$ x 1 mol of $Fe_2O_{3(s)}$ = 0.050 mol of $Fe_2O_{3(s)}$

55.85 g of $Fe_{(s)}$ 2 mol of $Fe_{(s)}$

STEP BY STEP METHOD:

2) n=m/M = 5.6g / 55.85 g/mol = 0.10 mol

3) $n_R = n_G$ x R/G = 0.10mol of $Fe_{(s)}$ x 1 mol of $Fe_2O_{3(s)}$ n= 0.050 mol of $Fe_2O_{3(s)}$

2 mol of $Fe_{(s)}$

2. When 4.00 x 10^{23} particles of methanol is burned, how many moles of water vapour are produced?

G R

1) 1 $CH_3OH_{(l)}$ + 3/2 $O_{2(g)}$ $\rightarrow$ 1 $CO_{2(g)}$ + 2 $H_2O_{(g)}$

UNIT ANALYSIS OR LINEAR METHOD

4.00x10^{23} part of $CH_3OH_{(l)}$ x 1 mol of $CH_3OH_{(l)}$ x 2 mol of $H_2O_{(g)}$ =1.3289…mol = 1.33 mol of $H_2O_{(l)}$

6.02E23 part of $CH_3OH_{(l)}$ 1 mol of $CH_3OH_{(l)}$

STEP BY STEP:

2) n=p/P **= 4.00x10^{23} part of $CH_3OH_{(l)}$/6.02E23 part of $CH_3OH_{(l)}$ per mol = 0.66445…mol of $CH_3OH_{(l)}$**

3) $n_r = n_g$ x R/G = 0.66445… mol of **$CH_3OH_{(l)}$ x 2 mol of $H_2O_{(g)}$ =1.3289…mol = 1.33 mol of $H_2O_{(l)}$**

1 mol of $CH_3OH_{(l)}$

3. If 122.6 g of solid potassium chlorate is heated, the crystals melt and decompose into solid potassium chloride and oxygen gas. How many moles of potassium chloride are formed?

G R

1) **2 $KClO_{3(s)}$ $\rightarrow$ 2 $KCl_{(s)}$ + 3 $O_{2(g)}$**

122.6 g ?

K = 39.10 x1 = 39.10

Cl = 35.45x1 = 35.45

O = 16.00x3 = 48.00

TOTAL 125.55g/mol

UNIT ANALYSIS OR LINEAR METHOD

122.6 g of $KClO_{3(s)}$ x 1 mol of $KClO_{3(s)}$ x 2 mol of $KCl_{(s}$ = 1.000 mol of $KCl_{(s)}$

122.55 g of $KClO_{3(s)}$ 2 mol of $KClO_{3(s)}$

STEP BY STEP METHOD

2) n=m/M =122.6 g / 122.55 g/mol =1.000 mol of $KClO_{3(s)}$

3) $n_R = n_G$ x R/G =1.000 mol of $KClO_{3(s)}$ x 2 mol of $KCl_{(s)}$ =1.000 mol of $KCl_{(s)}$

2 mol of $KClO_{3(s)}$

4. Black iron (III) oxide solid can be converted into water and iron metal when the iron (III) oxide is reacted with hydrogen gas. If 125 g of iron (III) oxide is reacted, how many moles of water are formed?

G R

1) 1 **$Fe_2O_{3(s)}$ + 3 $H_{2(g)}$ $\rightarrow$ 2 $Fe_{(s)}$ + 3 $H_2O_{(g)}$**

125 g ?

Fe = 55.85x2 =111.70

O = 16.00 x3 = 48.00

TOTAL 159.70g/mol

UNIT ANALYSIS OR LINEAR METHOD

125 g of $Fe_2O_{3(s)}$x 1 mol of $Fe_2O_{3(s)}$ x 3 mol of $H_2O_{(g)}$ = 2.34815… mol = 2.35 mol of $H_2O_{(g)}$

159.70 g of $Fe_2O_{3(s)}$ 1 mol of $Fe_2O_{3(s)}$

STEP BY STEP METHOD:

2) n=m/M = 125g / 159.70 g/mol = 0.7827175… mol of $Fe_2O_{3(s)}$

3) n_R=n_G x R/G=0.7827175…mol of $Fe_2O_{3(s)}$x 1 mole of $H_2O_{(g)}$ = 2.34815… mol = 2.35 mol of $H_2O_{(g)}$

2 moles of $Fe_2O_{3(s)}$

5. How many moles of zinc can react with hydrochloric acid to form 44.8 L of hydrogen gas at STP?

R G

1) 1 $Zn_{(s)}$ + 2 $HCl_{(aq)}$ → 1 $H_{2(g)}$ + $ZnCl_{2(aq)}$

? 44.8 L

UNIT ANALYSIS OR LINEAR METHOD:

$$44.8 \text{ L of } H_2 \times \frac{1 \text{ mol of } H_2}{22.4 \text{ L of } H_2} \times \frac{1 \text{ mol of Zn}}{1 \text{ mol of } H_2} = 2.00 \text{ mol of Zn}$$

STEP BY STEP METHOD:

2) n=v/V = 44.8 L / 22.4 L/mol =2.00 mol of H2

3) $n_R = n_G \times R/G = \frac{2.00 \text{ mol of } H_2 \times 1 \text{ mol of Zn}}{1 \text{ mol of } H_2} = 2.00 \text{ mol of Zn}$

6. Solutions of copper (II) sulphate and potassium phosphate are mixed. If 8.5 g of copper (II) phosphate form, how many moles of copper (II) sulphate react?

Cu = 63.55x3=190.65
P = 30.97x2=61.94
O = 16.00x8=128.00
TOTAL = 380.59g/mol

R G

1) **3 $CuSO_{4(aq)}$ + 2 $K_3PO_{4(aq)}$ → 3 $K_2SO_{4(aq)}$ + 1 $Cu_3(PO_4)_{2(s)}$**

? mol 8.5 g

2) $n=m/M = 8.5 \text{ g of } Cu_3(PO_4)_{2(s)} / 380.59 \text{g/mol of } Cu_3(PO_4)_{2(s)} = 0.02233\ldots \text{mol of } Cu_3(PO_4)_{2(s)}$

3) $n_R = n_G \times R/G = \frac{0.500 \text{ mol of } Fe_3N_{2(s)} \times 1 \text{ mol of } Sn_3N_{2(s)}}{2 \text{ mol of } Fe_3N_{2(s)}} = 0.250 \text{ mol of tin (IV) phosphate}$

LINEAR: $$8.5 \text{ g of } Cu_3(PO_4)_{2(s)} \times \frac{1\text{mol of } Cu_3(PO_4)_{2(s)}}{380.59 \text{g/mol of } Cu_3(PO_4)_{2(s)}} \times \frac{1 \text{ mol of } Sn_3N_{2(s)}}{2 \text{ mol of } Fe_3N_{2(s)}} = 0.250 \text{ mol of tin (IV) phosphate}$$

7. In the manufacturing of nitric acid, nitrogen dioxide gas reacts with water to from nitric acid and nitrogen monoxide gas. How many moles of nitrogen dioxide gas reacts if 120.6 L of nitrogen monoxide gas is formed at SATP?

R G

1) 3 **$NO_{2(g)}$ + $H_2O_{(l)}$ → 2 $HNO_{3(aq)}$ + 1 $NO_{(g)}$**

? 120.6 L

UNIT ANALYSIS OR LINEAR METHOD:

$$120.6 \text{ L of } NO_{2(g)} \times \frac{1 \text{ mol of } NO_{2(g)}}{24.8 \text{ L of } NO_{2(g)}} \times \frac{3 \text{ mol of } NO_{(g)}}{1 \text{ mol of } NO_{2(g)}} = 14.59 \text{ moles of } NO_{(g)}$$

STEP BY STEP METHOD:

2) $n=v/V = 120.6 \text{ L} / 24.8 \text{ mol/L} = 4.863 \text{ mol of } NO_{2(g)}$

3) $n_R = n_G \times R/G = \frac{4.863 \text{ mol of } NO_{2(g)} \times 3 \text{ mol of } NO_{(g)}}{1 \text{ mol of } NO_{2(g)}} = 14.59 \text{ moles of } NO_{(g)}$

8. The thermite reaction is used in welding iron and steel. Aluminium and iron (III) oxide are ignited at high temperatures to produce aluminium oxide and iron. If 15.0 g of aluminium is used in this reaction, how many moles of aluminium oxide will be produced?

G R

Step 1) 2 $Al_{(s)}$ + $Fe_2O_{3(s)}$ → 1 $Al_2O_{3(s)}$ + 2 $Fe_{(s)}$

15.0g ? mol

Step 2) n=m/M = 15.0g of Al(s)/26.98g/mol = 0.55596…mol of Al(s)

Step 3) $n_R = n_G \times R/G = 0.55596\ldots \text{mol of Al(s)} \times 1 \text{ mol of } Al_2O_{3(s)} / 2 \text{ mol of Al(s)} = 0.27798\ldots$
$= 0.278 \text{mol of } Al_2O_{3(s)}$

LINEAR: $$15.0\text{g of Al(s)} \times \frac{1 \text{ mol of Al(s)}}{26.98\text{g of Al(s)}} \times \frac{1 \text{ mol of } Al_2O_{3(s)}}{2 \text{ mol of Al(s)}} = 0.27798\ldots \text{ mol} = 0.278\text{mol of } Al_2O_{3(s)}$$

Worksheet 3.4: Quantity to Quantity Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. How many particles of aluminium oxide must be decomposed to produce 80.0 g of oxygen gas at STP?

   R G

   1) $2\,Al_2O_{3\,(s)} \rightarrow 4\,Al_{(s)} + 3\,O_{2(g)}$

   UNIT ANALYSIS OR LINEAR METHOD:

   80.0 g of $O_{2(g)}$x1 mol of $O_{2(g)}$ x 2 mol of $Al_2O_{3(s)}$x6.02E23 particles of $Al_2O_{3(s)}$=1.00E24 part of $Al_2O_{3(s)}$

   32.00 g of $O_{2(g)}$ 3 mol of $O_{2(g)}$ 1 mol of $Al_2O_{3(s)}$

   STEP BY STEP:

   2) n = m/M = 80.0g /32.00 g/mol = 2.5 mol of O_2

   3) $n_R = n_G$ x R/G = 2.5 mol of O_2 x 2 mol of Al_2O_3 = 1.66666... mol of $Al_2O_{3(s)}$

   3 mol of O_2

   4) p = n P = 1.6666...mol x 6.02 E 23 particles/mol = 1.00 E 24 or 1.00 x 10^{24} particles of $Al_2O_{3(s)}$

2. Natural gas is mainly made up of methane. What mass of methane must be burned to produce 56.0 L of carbon dioxide at STP?

   R G

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

LINEAR: **56.0 L of CO_2 x 1 mol of CO_2 x 1 mol of CH_4 x 16.05 g of CH_4 = 40.1 g of $CH_{4(g)}$**

22.4 L of CO_2 1 mol of CO_2 1 mol of CH_4

STEP BY STEP:

2) n=v/V = **56.0 L of CO_2/ 22.4 L of CO_2 = 2.5 mol of CO_2**

3) $n_R = n_G$ x R/G = 2.5 mol of CO_2 x 1 mol of CH_4/1 mol of CO_2 = 2.5 mol of CO2

4) m = nM = 2.5 mol of CO_2 x 16.05g/mol of CO_2 = 40.1 g of $CH_{4(g)}$

3. Aluminium metal is refined from bauxite ore. In the refining process, aluminium oxide decomposes to aluminium and oxygen gas. What mass of aluminium can be produced from **2.04 kg** of aluminium oxide?

   G R

   1) 2 $Al_2O_3\,(s) \rightarrow 4\,Al\,(s) + 3\,O_2(g)$

LINEAR: 2040 g of Al_2O_3 x 1 mol of Al_2O_3 x 4 mol of Al x 26.98 g of Al = 1079.6 g = 1.08 kg of Al

101.96 g of Al_2O_3 2 mol of Al_2O_3 1 mol of Al

STEP BY STEP:

2) **n =m/M = 2040 g of Al_2O_3/ 101.96g/mol of Al_2O_3 = 20.0078… mol of Al_2O_3**

3) **$n_R = n_G$ x R/G = 20.0078…mol of Al_2O_3 x 4 mol of Al/2 mol of Al_2O_3 = 40.0156… mol of Al(s)**

4) **m = nM = 40.0156… mol of Al(s) x 26.98 g/mol of Al = 1079.6 g = 1.08 kg of Al**

4. Sodium hydrogen carbonate can be used to neutralize acids. If sodium hydrogen carbonate reacts with hydrochloric acid, what volume of carbon dioxide gas at STP can be produced by 16.8 g of sodium hydrogen carbonate? NOTE: Sodium chloride and water vapour is also produced.

   G R

   1) 1 $NaHCO_3\,(aq) + 1\,HCl(aq) \rightarrow 1\,CO_2\,(g) + 1\,NaCl\,(aq) + 1\,H_2O(l)$

LINEAR:16.8 g of $NaHCO_3$ x 1 mol of $NaHCO_3$ x 1 mol of CO_2 x 22.4 L of CO_2 = 4.48 L of $CO_{2(g)}$

84.01 of $NaHCO_3$ 1 mol of $NaHCO_3$ 1 mol of CO_2

STEP BY STEP:

2) n=m/M = **16.8 g of $NaHCO_3$/ 84.01 g/mol of $NaHCO_3$ = 0.19997…mol of $NaHCO_3$**

3) **$n_R = n_G$ x R/G =0.19997…mol of $NaHCO_3$x1mol of CO_2/1mol of $NaHCO_3$ = 0.19997…mol of $NaHCO_3$**

4) **v = nV =0.19997…mol of $NaHCO_3$ x 22.4 L of CO_2 = 4.48 L of $CO_{2(g)}$**

5. Photography film is coated with silver chloride, which is produced when silver nitrate reacts with sodium chloride. What mass of silver chloride can be made from 11.7 g of sodium chloride?

G R

1) $1\text{ NaCl (aq)} + 1\text{ AgNO}_3\text{ (aq)} \rightarrow 1\text{ AgCl (aq)} + 1\text{ NaNO}_3\text{(aq)}$

LINEAR: $$11.7\text{ g of NaCl} \times \frac{1\text{ mol of NaCl}}{58.44\text{g of NaCl}} \times \frac{1\text{ mol of AgCl}}{1\text{ mol of NaCl}} \times \frac{143.32\text{ g of AgCl}}{1\text{ mol of AgCl}} = 28.7\text{ g of AgCl}$$

STEP BY STEP:

2) n = m/M = **11.7 g/58.44g/mol = 0.200205…mol of NaCl**

3) **$n_R = n_G \times R/G$ =** $$0.200205\ldots\text{mol of NaCl} \times \frac{1\text{ mol of AgCl}}{1\text{ mol of NaCl}} = 0.200205\ldots\text{mol of AgCl}$$

4) m = nM = 0.200205…mol of AgCl x 143.32g/mol = 28.693…g = 28.7g of AgCl

6. Ammonia reacts with hydrochloric acid to produce ammonium chloride. What volume of ammonia at SATP is needed to produce 36.1 g of ammonium chloride?

R G

1) $1\text{ NH}_3\text{ (g)} + 1\text{ HCl(aq)} \rightarrow 1\text{ NH}_4\text{Cl(aq)}$

LINEAR: $$36.1\text{ g of NH}_4\text{Cl} \times \frac{1\text{ mol of NH}_4\text{Cl}}{53.50\text{ g of NH}_4\text{Cl}} \times \frac{1\text{ mol of NH}_3}{1\text{ mol of NH}_4\text{Cl}} \times \frac{24.8\text{ L of NH}_3}{1\text{ mol of NH}_3} = 16.7\text{ L of NH}_3$$

STEP BY STEP:

2) n = m/M = 36.1g / 53.50g/mol = 0.674766…mol of NH4Cl

3) **$n_R = n_G \times R/G$ =** $$0.674766\ldots\text{mol of NH4Cl} \times \frac{1\text{ mol of NH3}}{1\text{ mol of NH4Cl}} = 0.674766\ldots\text{ mol of NH3}$$

4) v = n V = 0.674766… mol of NH3 x 24.8L/mol = 16.734… L = 16.7 L of NH_3

7. If sulphuric acid reacts with 29.4 g of potassium hydroxide, what mass of potassium sulphate is produced?

G R

1) $2\text{ H}_2\text{SO}_4\text{ (aq)} + 2\text{ KOH(aq)} \rightarrow 1\text{ K}_2\text{SO}_4\text{(aq)} + 2\text{ HOH(l)}$

LINEAR: $$29.4\text{ g of KOH} \times \frac{1\text{ mol of KOH}}{56.11\text{ g of KOH}} \times \frac{1\text{ mol of K}_2\text{SO}_4}{2\text{ mol of KOH}} \times \frac{174.27\text{ g of K}_2\text{SO}_4}{1\text{ mol of K}_2\text{SO}_4} = 45.7\text{ g of K}_2\text{SO}_4$$

STEP BY STEP:

2) n = m/M = 29.4g / 56.11g/mol =

3) **$n_R = n_G \times R/G$ =**

4) m = nM

8. If sodium iodide reacts with lead (II) nitrate, what mass of lead (II) nitrate will be required to produce 150 g of precipitate?

R G

1) $2\text{ NaI (aq)} + 1\text{ Pb(NO}_3)_2\text{(aq)} \rightarrow 1\text{ PbI}_2\text{ (s)} + 2\text{ NaNO}_3\text{(aq)}$

LINEAR: $$150\text{ g of PbI}_2 \times \frac{1\text{ mol of PbI}_2}{461\text{ g of PbI}_2} \times \frac{1\text{ mol of Pb(NO}_3)_2}{1\text{ mol of PbI}_2} \times \frac{331.22\text{ g of Pb(NO}_3)_2}{1\text{ mol of Pb(NO}_3)_2} = 108\text{ g of Pb(NO}_3)_2$$

STEP BY STEP:

2) n = m/M =

3) **$n_R = n_G \times R/G$ =**

4) m = nM

Worksheet 2.5: Limiting & Excess Reagents

Directions: For each of the following, write a balanced equation and determine the limiting reagent
& the excess reagent (if they are present).

1. 5.0 mol of gasoline ($C_8H_{18(l)}$) burns 47.0 mol of oxygen at STP. How many **moles of carbon dioxide are present at STP**? B) How many moles of excess remains?

Excess ~~G~~ R used ~~G~~=L R
(2) (25) (16) (18)
Step 1) 1 $C_8H_{18(l)}$ + 12.5 $O_{2(g)}$ → 8 $CO_{2(g)}$ + 9$H_2O_{(g)}$

Step 3) 5.0 mol of C_8H_{18} x 8 mol of CO_2 = 40 mol of $CO_{2(g)}$ (C_8H_{18} is EXCESS)
1 mol of $C_8H_{18(l)}$

47.0 mol x 8 mol of $CO_{2(g)}$= 30.08 mol of $CO_{2(g)}$ (LIMITING)=30.1 mol of $CO_{2(g)}$
12.5 mol of $O_{2(g)}$

b) Step 3) 47.0 mol of O_2 x 1 mol of C_8H_{18} = 3.76 mol of C_8H_{18} used
12.5 mol of O_2

Remains = Original Excess (Step 2) – Used Excess (Step 3)
= 5.0 mol – 3.76 mol = 1.24 mol = 1.2 mol left over (2 sig digs)

2. 18.0 g of hydrogen is added to 6.0 g of oxygen. How **many grams of water** are formed? How much excess reagent is left over in grams?

G1 ~~G2~~ R2 **R**
Step 1) 1 $O_{2(g)}$ + 2 $H_{2(g)}$ →2 $H_2O_{(g)}$
Step 2) n=m/M = 18.0g/2.02g/mol of H2 = 8.9…mol of water
n = m/M = 6.0g/32.0g/mol = 0.1875 mol of oxygen
Step 3) 8.9… mol of H_2 x 2mol of water = 8.9… mol of water (H_2 is EXCESS)
2mol of H_2
0.1875mol of O_2 x 2mol of water = 0.375 mol of water (O_2 is LIMITING)
1mol of O_2
Step 4) 0.375 mol x 18.02g/mol = 6.8 g of water is produced

b) Step 2) n = m/M = 6.0g/32.0g/mol = 0.1875 mol of oxygen
Step 3) 0.1875 mol of O_2 x 2mol of H_2 = 0.375 mol of H_2 used
1mol of O_2
Remaining = Original moles of Excess – Used moles of Excess
= 8.9…mol of water – 0.375… mol = 8.545…mol remaining
Step 4) m=nM = 8.545…mol x 2.02g/mol = 17.2… = 17 g

3. 22.4 mL of methane reacts with 22.4 mL of oxygen at SATP. How many moles of water are made? **~~G~~ R used G R**

Step 1) 1 $CH_{4(g)}$ + 2 $O_{2(g)}$ → $CO_{2(g)}$ + 2 $H_2O_{(g)}$
Step 2) n = v/V n = v/V
= 0.0224/24.8 = 0.0224/24.8
= 9.03…E-4 mol =9.03…E -4 mol
Step 3) 9.03…E-4 x 2mol $H_2O_{(g)}$ 9.03…E-4 mol of O_2 x 2mol $H_2O_{(g)}$
1mol $CH_{4(g)}$ 2mol $O_{2(g)}$
= 1.806..E-3 mol (EXCESS) = 9.03E-4 mol of water (O_2 is LIMITING)
B) Step 3) =9.03…E -4 mol of O_2 x 1 mol of CH_4 = 4.516..E-4 mol of CH_4 used
2 mol of O_2

EXCESS LEFT OVER = ORIGINAL(STEP 2) – USED (STEP 3 the 3rd time)
EXCESS LEFT OVER = 9.03…E-4 mol - 4.516..E-4 mol of CH_4 = 4.52 E-4 mol are left over

4. 26 g of magnesium react with 1.00 **mol** of hydrochloric acid.

a) What **volume of Hydrogen gas** is made at **STP**?

~~G1~~ R used | G2 | **R**

Step 1) **1 $Mg_{(s)}$ + 2 $HCl_{(aq)}$ → 1 $H_{2(g)}$ + $MgCl_{2(aq)}$**

Step 2) **n = m/M** **= 26/24.31g/mol = 1.069…mol** | **1.00 mol**

Step 3) **$\frac{1.069\ldots mol \times 1 mol\ H_{2(g)}}{1 mol\ Mg_{(s)}}$** **=1.0695…mol (EXCESS)** | **$\frac{1.00\ mol \times 1\ mol\ H_{2(g)}}{2\ mol\ HCl_{(aq)}}$** **= 0.500 mol (HCl is LIMITing)**

Step 4) **v = nV** **0.500 mol of $H_{2(g)}$ x 22.4L/mol = 11.2 L of $H_{2(g)}$**

b) How much excess reagent is left over?

~~G~~ R used | G

Step 1) **1 $Mg_{(s)}$ + 2 $HCl_{(aq)}$ → 1 $H_{2(g)}$ + $MgCl_{2(aq)}$**

Step 2) **1.00 mol**

Step 3) **$\frac{1.00\ mol\ of\ HCl_{(aq)} \times 1\ mol\ Mg_{(s)}}{2\ mol\ HCl_{(aq)}}$ = 0.500 mol of $Mg_{(s)}$ is used**

Step 4) Excess = Original moles of Excess – used moles of Excess

= 1.069…mol –0.500mol = 0.570 mol of $Mg_{(s)}$ left

m= n M = 0.5695… mol of Mg x 24.31g/mol = 13.8 g of $Mg_{(s)}$ left over

5. 3.02×10^{23} formula units of sodium react with 12 L of chlorine gas at STP. How much excess reagent is left over if the limiting is all used up?

G_1 = L | G_2 = E | **R**

Step 1) **2 $Na_{(s)}$ + 1 $Cl_{2(g)}$ → 2 $NaCl_{(aq)}$**

Step 2) **n = p/P** **= 3.02E23FU/6.02E23 FU/mol = 0.5016… mol of $Na_{(s)}$** | **n = v/V = 12L/22.4L/mol = 0.535714… mol of $Cl_{2(g)}$**

Step 3) **$\frac{0.5016\ldots \times 2\ mol\ NaCl_{(aq)}}{2\ mol\ Na_{(s)}}$ =0.502 mol of NaCl (Na LIMIT)** | **$\frac{0.5357..\ mol \times 2\ mol\ NaCl_{(aq)}}{1\ mol\ Cl_{2(g)}}$ = 1.0714… mol of NaCl (Cl2 Exce)**

G =L | **~~G_2~~ R**

Step 1) **2 $Na_{(s)}$ + 1 $Cl_{2(g)}$ → 2 $NaCl_{(aq)}$**

Step 2) **0.5016… mol of $Na_{(s)}$**

Step 3) **$\frac{0.5016\ldots mol\ of\ Na_{(s)} \times 1\ mol\ Cl_{2(g)}}{2\ mol\ Na_{(s)}}$ = 0.2508.. mol of $Cl_{2(g)}$ used**

Step 4) Excess = original moles of Excess – used moles of Excess

= 0.535714… mol of $Cl_{2(g)}$– 0.2508.. mol = 0.28 mol of $Cl_{2(g)}$ left

6. Describe a limiting reagent and an excess reagent.

- **A limiting reagent is a reactant that controls how much product you have (it is the first reagent to be used up.**
- **An excess reagent is a reactant that is left over (it is not all used up)**

Worksheet 2.6: Percent yield and Percent error

Directions: For each of the following write a balanced equation and determine the theoretical yield, actual yield, percent yield & the percent error.

1. 8.0 mol of sulphur dioxide decomposes and actually **produces** 7.0 mol of oxygen gas.

G R = TY

Step 1) 8 $SO_{2(g)}$ → $S_{8(s)}$ + 8 $O_{2(g)}$

8.0 mol 7.0 *mol* = AY; TY = ?

Step 3) 8.0 mol $SO_{2(g}$ x 8 mol of $O_{2(g)}$ = 8.0 *mol* of $O_{2(g)}$ is the TY

8 mol of $SO_{2(g)}$

Step 5) % yield = AY/TY x100 7.0 *mol*/ 8.0 *mol* x 100 = 88 %

% error = \ (TY – AY) \ = 12.5 = 13 % (100 – 87.5 = 13%)

TY

2. 26.0 g of aluminum reacts with a solution of calcium nitrate and produces 3.00 moles of calcium. **G R = TY = ?**

Step 1) 2 $Al_{(s)}$ + 3 $Ca(NO_3)_{2(aq)}$ → 3 $Ca_{(s)}$ + 2 $Al(NO_3)_{3(aq)}$

Step 2) 26.0g/26.98g/mol 3.00 *mol* = AY

= 0.964… mol

Step 3) 0.964… mol x 3 mol of $Ca_{(s)}$ = 1.44… *mol* of $Ca_{(s)}$ = TY

2 mol of $Al_{(s)}$

Step 5) % yield = AY/TY x 100 3.00 mol / 1.44… mol x 100 = 208% because of of the solution (not evaporated)

% error = (TY - AY)/TY x 100 = +108%

3. 6.50 mol of potassium chlorate solid is heated and breaks down into potassium chloride solid and 223 L of oxygen gas at SATP.

G R (TY) = ?

Step 1) 2 $KClO_{3(s)}$ → 2$KCl_{(s)}$ + 3 $O_{2(g)}$

Step 2) 6.50 mol 223L = AY

(n=v/V= 223L/24.8L/mol =8.99… mol)

Step 3) 6.50 mol $KClO_3$ x 3 mol of O_2 = 9.75… mol of O_2 = TY

2mol of $KClO_3$

Step 4) v = nV = 9.75 x 24.8 = 241.8 L = TY (Not necessary if you changed AY to moles)

Step 5) % yield AY/TY x 100 = 223L/241.8 L x 100% = 92.2% (%yield =8.99…/9.75 x 100%)

% error = (TY-AY)/TY x 100% = (241.8L – 223L)/241.8L = 7.78%

4. 33.6 L of methane burns and produces 2.00 mol of carbon dioxide gas at STP.

G R

Step 1) balance 1 $CH_{4(g)}$ + 2 $O_{2(g)}$ → 1 $CO_{2(g)}$ + 2 $H_2O_{(g)}$

Step 2) n = v/V = 33.6 /22.4 = 1.5 mol 2.00 mol = AY

Step 3) mole ratio **1.5 mol of CH_4 x 1 mol of $CO_{2(g)}$ = 1.5 mol of CO_2 = TY**

1 mol of $CH_{4(g)}$

Step 5) % yield = AY/TY x 100 = 2.00 mol/1.5 mol x 100 = 133 %

% error = 33.3% (answer becomes positive)

5. Sulphuric acid reacts with 29.4 g of potassium hydroxide and produces 40.5 g of potassium sulphate G R

Step 1) $H_2SO_{4\,(aq)}$ + 2 $KOH_{(aq)}$ → 2 HOH $_{(l)}$ + 1 $K_2SO_{4\,(aq)}$

Step 2) **n = m/M = 29.4g/56.11g/mol 40.5g/174.27= AY**

= 0.5239… mol of KOH = 0.23239… mol = AY

Step 3) 0.5239…mol KOH x1mol of $K_2SO_{4\,(aq)}$=0.26195… mol TY

2mol of $KOH_{(aq)}$

Step 4) Both AY and TY are in moles. (m=0.26195x174.27= 45.65…g)

Step 5) %yield = AY/TY = 0.23239…mol/0.26195…mol x 100 = 88.7 %

(40.5g / 45.65…g = 88.7%)

% error = (AY–TY)/TYx100 =(0.26195-0.23239)/ 0.26195x100= 11.3%

6. Describe percent yield and percent error.

Percent yield: a ratio between AY and TY as a percent; how much you produce compared to what you should produce.

Percent error: an indication of error (human, instrumental & experimental).

Worksheet 2.7: Limiting Reagents and Percent Yield

1. Methane gas burns at STP.

a. If 0.500 mol of methane is burned in 2.50 mol of oxygen, what is the limiting reagent? **G1** **G2** **R**

Step 1) **1 $CH_{4(g)}$ + 2 $O_{2(g)}$ → $CO_{2(g)}$ + 2 $H_2O_{(g)}$**

Step 2) **0.500 mol** **2.50 mol**

Step 3) **0.500mol of CH_4 x 2mol of $H_2O_{(g)}$** **2.50 mol of O2 x 2mol of $H_2O_{(g)}$**

1 mol of $CH_{4(g)}$ **2mol of $O_{2(g)}$**

= 1.00 mol of water ← TY **2.50 mol of water**

CH_4 is limiting **O_2 is excess**

b. What is the theoretical yield, in moles, of water?

1.00 mol of water is the theoretical yield (use the limiting side

2. Sodium and chlorine are mixed together.

a. What is the limiting reagent if there is 10.0 g of sodium and 20.0 g of chlorine?

G1 G2 R

1) 2 **$Na_{(s)}$ + 1 $Cl_{2(g)}$ →** 2 **$NaCl_{(aq)}$**

2) **n=m/M = 10.0g/22.99g/mol** **n=20.0g/70.90g/mol**

= 0.4349717…mol **= 0.282087447…mol**

3) **x 2 mol of $NaCl_{(aq)}$/2mol of $Na_{(s)}$** **x 2 mol of $NaCl_{(aq)}$/1 mol of $Cl_{2(g)}$**

= 0.4349…mol of $NaCl_{(aq)}$ (smaller) **= 0.56417…mol of $NaCl_{(aq)}$**

$Na_{(s)}$ is LIMITING **$Cl_{2(g)}$ is EXCESS**

UNIT ANALYSIS OR LINEAR METHOD:

10.0g x 1 mol of $Na_{(s)}$ x 2 mol of $NaCl_{(aq)}$ x 58.44 g of $NaCl_{(aq)}$= 25.419… g of NaCl LIMIT

22.99 g 2 mol of $Na_{(s)}$ 1 mol of $NaCl_{(aq)}$

20.0g x 1 mol of Cl_2 x 2 mol of $NaCl_{(aq)}$ x 58.44 g of $NaCl_{(aq)}$ = 32.970… g of NaCl EXCESS

70.90 g 1 mol of $Cl_{2(s)}$ 1 mol of $NaCl_{(aq)}$

b. How many grams of the product are produced?

4) **m = nM_{NaCl} = 0.4349717…mol of $NaCl_{(aq)}$ x 58.44g/mol = 25.4 g of $NaCl_{(aq)}$**

3. In the synthesis of sulphuric acid, one step involves the mixing of sulphur dioxide with oxygen to produce sulphur trioxide. If 175 L of sulphur dioxide was mixed with 85 L of oxygen at SATP, how **many litres of sulphur trioxide** is produced?

G1 = E **G2 = L** **R**

STEP 1) **2 $SO_{2(g)}$ + 1 $O_{2(g)}$ → 2 $SO_{3(g)}$**

175 L **85L** **?**

STEP 2) **n = v/V = 175L/24.8L/mol** **n = 85L/24.8L/mol**

n = 7.0564…mol $SO_{2(g)}$ **n = 3.4274…mol of $O_{2(g)}$**

STEP 3) **x 2 mol $SO_{3(g)}$ = 7.0564… mol** **x 2 mol $SO_{3(g)}$ =6.8548…mol of $SO_{3(g)}$ (LIMITING)**

2 mol $SO_{2(g)}$ **1 mol of $O_{2(g)}$**

STEP 4) v=nV = 6.8548…mol of $SO_{3(g)}$ x 24.8 = 170 L of $SO_{3(g)}$

UNIT ANALYSIS OR LINEAR METHOD:

For **$SO_{2(g)}$: 175L x 1 mol of $SO_{2(g)}$ x 2 mol of $SO_{3(g)}$ x 24.8 L of $SO_{3(g)}$ = 174.99 … L of $SO_{3(g)}$**

24.8 L of $SO_{2(g)}$ 2 mol of $SO_{2(g)}$ 1 mol of $SO_{3(g)}$

For **$O_{2(g)}$: 85L x 1 mol of $O_{2(g)}$ x 2 mol of $SO_{3(g)}$ x 24.8 L of $SO_{3(g)}$ = 170 L of $SO_{3(g)}$**

24.8 L of $O_{2(g)}$ 1 mol of $O_{2(g)}$ 1 mol of $SO_{3(g)}$

4. Adipic acid ($C_6H_{10}O_{4(s)}$), a raw material for nylon, is made by the oxidation (reacting with oxygen) of cyclohexane ($C_6H_{12(s)}$). Water is a by-product.

a. How many **moles of oxygen gas** would be needed to make 40.0 mol of adipic acid?

R G

STEP 1) $C_6H_{12(s)}$ + **2.5** $\mathbf{O_{2(g)}}$ → **1** $C_6H_{10}O_{4(s)} + H_2O(l)$

STEP 2) Already in moles **?** **40.0mol = n_g**

STEP 3) $\mathbf{40.0\ mol}\ C_6H_{10}O_{4(s)}$ **of** $\times \dfrac{\mathbf{2.5\ mol\ O_{2(g)}}}{\mathbf{1\ mol}\ C_6H_{10}O_{4(s)}}$ **= 100 mol of $O_{2(g)}$**

STEP 4) Not needed

UNIT ANALYSIS OR LINEAR METHOD:

For $\mathbf{SO_{2(g)}}$: $\mathbf{40.0\ mol\ of}\ C_6H_{10}O_{4(s)} \times \dfrac{\mathbf{2.5\ mol\ of\ O_{2(g))}}}{\mathbf{1\ mol\ of}\ C_6H_{10}O_{4(s)}}$ **= 100 mol of $O_{2(g)}$**

b. If 2.00 mol of oxygen is reacted with 164 g of cyclohexane, what is the theoretical **yeild of adipic acid** in grams?

G1 = L R

STEP 1) (G2) 1 $C_6H_{12(s)}$ + **2.5** $\mathbf{O_{2(g)}}$ → **1** $C_6H_{10}O_{4(s)} + H_2O(l)$

STEP 2) n=m/M=164g/84.18g/mol **2.00 mol** **?**

n=1.9482… mol of $C_6H_{12(s)}$

STEP 3) $\mathbf{1.9482…\ mol} \times \dfrac{\mathbf{1\ mol}\ C_6H_{10}O_{4(s)}}{\mathbf{1\ mol}\ C_6H_{12(s)}}$ $\mathbf{2.00\ mol} \times \dfrac{\mathbf{1\ mol\ of}\ C_6H_{10}O_{4(s)}}{\mathbf{2.5\ mo\ of\ O_{2(g)}}}$

= 1.9482… mol of $C_6H_{10}O_{4(s)}$ **= 0.8 mol of $C_6H_{10}O_{4(s)}$** (O_2 is LIMITING)

STEP 4) 0.8 mol of $C_6H_{10}O_{4(s)}$ x 146.16 g/mol = 116.928 g =117 g of $C_6H_{10}O_{4(s)}$=TY(3 sig dig)

UNIT ANALYSIS OR LINEAR METHOD:

For $\mathbf{O_{2(g)}}$: $\dfrac{\mathbf{2\ mol\ of}\ O_{2(g)}\ \mathbf{x1\ mol}}{\mathbf{2.5\ mol}\ \ O_{2(g)}} \dfrac{\mathbf{x146.16g\ of}\ C_6H_{10}O_{4(s)}}{1\ \text{mol of}\ C_6H_{10}O_{4(s)}}$ **=** 117 g of $C_6H_{10}O_{4(s)}$ (3 sig dig)

For $C_6H_{12(s))}$: $\dfrac{\mathbf{164gx1mol\ x\ \ 1\ mol}}{\mathbf{84.18g\ \ \ 1\ mol}} \dfrac{\mathbf{x146.16g\ of}\ C_6H_{10}O_{4(s)}}{1\ \text{mol of}\ C_6H_{10}O_{4(s)}}$ **=** 285 g of $C_6H_{10}O_{4(s)}$ (3 sig dig)

c. If 85 g of acid was produced in b) what is the percent yield?

(Use rounded answer from b)

%yield = AY/TY x 100% = 85 g / 117 g of $C_6H_{10}O_{4(s)}$ x 100% = **72.6% yield**

5. A chemist, new to the behaviour of chlorine toward hydrocarbon compounds, tried to make dichloromethane ($CH_2Cl_{2(g)}$), by mixing 5500 mL of chloromethane ($CH_3Cl_{(g)}$) and 5500 mL of chlorine at STP. Hydrogen chloride gas was a by product. After the reaction was complete, some chloromethane remained unchanged and 12.8 g of dichloromethane was obtained.

a. Which reactant is excess?

G1 = E **G2 = L** **R (TY)**

STEP 1) **1** $\mathbf{CH_3Cl_{(g)}}$ **+** **1.5** $\mathbf{Cl_{2(g)}}$ **→** **1** $\mathbf{CH_2Cl_{2(g)}}$ **+** $\mathbf{HCl_{(g)}}$

5500 mL **5500 mL** **12.8 g = AY**

STEP 2) n= v/V **= 5.5L/22.4L/mol** **5.5L/22.4L/mol**

=0.2455…mol **=0.2455…mol**

STEP 3) **x 1mol/1mol=0.2455…mol** **x 1 mol/1.5 mol = 0.1636…mol (Cl2 is limiting)**

b. How much dichlormethane can theoretically be produced?

STEP 4) **m = nM = 0.1636…mol x 84.93 g/mol = 13.89… g = 13.9 g = TY**

c. What is the percent yield?

%yield = AY/TY x 100% = 12.8 g / 13.9 g x 100% = 92.086…% = 92.1%

d. What is the percent error?

%error = (TY-AY)/TY x 100% = (13.9 – 12.8)/13.9 x 100% = 7.91 %

Worksheet 2.8: Stoichiometry Review

1. A 34.5 g sample of sodium hydroxide solution is reacted with excess phosphoric acid. What is the **mass of sodium phosphate** that will form?

G **R**
1) 3 $NaOH_{(s)}$ + $H_3PO_{4(aq)}$ → $3HOH_{(l)}$ + 1 $Na_3PO_{4(aq)}$
UNIT ANALYSIS OR LINEAR METHOD:
(2) (3) (4)
34.5g x 1 mol of NaOH x 1mol of Na_3PO_4 x 163.94 g of Na_3PO_4 =47.1 g of sodium phosphate
40.00g 3 mol of NaOH 1 mol of Na_3PO_4

2. A 75.0 g sample of lithium carbonate reacts with 120 g of aluminium nitrate. What mass of precipitate will form?

G1=E=R G2 = LR R
1) 3 $Li_2CO_{3(aq)}$ + 2 $Al(NO_3)_{3(aq)}$ → 6 $LiNO_{3(aq)}$ + 1 $Al_2(CO_3)_3$ (s)
2) 75.0 g/73.89 = 1.0150… mol 120g/213.01=0.56333...mol ? g
3) 1.015.. x 1 mol = 0.33… mol 0.563... x 1 mol of = 0.28…mol (LIMITING)
3mol (Excess) 2 mol
4) 0.28…mol of $Al_2(CO_3)_{3(s)}$ x 233.99g/mol= 65.9 g of $Al_2(CO_3)_{3(s)}$

UNIT ANALYSIS or LINE METHOD
75.0 g x 1 mol x 1 mol of $Al_2(CO_3)_3$ x 233.99 g of $Al_2(CO_3)_{3(s)}$ =79.2 g
73.80 g 3 mol of $Li_2CO_{3(aq)}$ 1 mol of $Al_2(CO_3)_{3(s)}$

120 g x 1mol $Al(NO_3)_{3(aq)}$ x 1mol of $Al_2(CO_3)_3$ x 233.99 g of $Al_2(CO_3)_{3(s)}$ = 65.9 g (LIMITED)
213.01 g 2 mol of $Al(NO_3)_{3(aq)}$ 1 mol of $Al_2(CO_3)_{3(s)}$
b) HOW MUCH EXCESS LEFT OVER
~~G~~ R EXCESS G = LR
3 Li_2CO_3(aq) + 2 $Al(NO_3)_3$ (aq) → 6 $LiNO_3$ (aq) + 1 $Al_2(CO_3)_3$ (s)
120g/213.01 = 0.563333...mol

=0.56333...mol x 3 mol of Li_2CO_3 x 73.89 g/mol of Li_2CO_3 = 62.4… g of Li_2CO_3 used
2 mol of $Al(NO_3)_3$
ORIGINAL - USED
75.0g -62.4…g = 12.6 g of EXCESS LEFT OVER

3. A 45.0 g sample of ethanol burns in the presence of 105 L of oxygen gas. (assume STP). What is the percent yield if **50.0 g of carbon dioxide** is formed?

G1=L G2=E R
1) 1 $C_2H_5OH_{(l)}$ + 3 $O_{2(g)}$ → 2 $CO_{2(g)}$ + 3 $H_2O_{(g)}$
45.0g 105 L 50.0g/44.01g = 1.13…mol
(2) (3) (4)
45.0g x 1 mol of C_2H_5OH x 2 mol of $CO_{2(g)}$=1.953…mol x 44.01 g of $CO_{2(g)}$ = 85.97..g of CO2
46.08g 1 mol of C_2H_5OH 1 mol of $CO_{2(g)}$ ethanol limiting

105L x 1 mol of O2 x x 2 mol of $CO_{2(g)}$ = 4.6…mol 44.01 g of $CO_{2(g)}$ = 137.5 of CO2
22.4 L 3 mol of O2 1mol of $CO_{2(g)}$ oxygen excess

%yield = AY/TY x 100% = 50.0g/85.97.. x 100% = 58.16…% = 58.2 %
%yield = AY/TY x 100% = 1.136mol/1.953.. x 100% = 58.16…% = 58.2 %
EXCESS LEFT OVER:
1) 1 $C_2H_5OH_{(l)}$ + 3 $O_{2(g)}$ → 2 $CO_{2(g)}$ + 3 $H_2O_{(g)}$
45.0g x 1 mol of C_2H_5OH x 3 mol of $O_{2(g)}$ =2.929…mol x 22.4 L of $O_{2(g)}$ = 65.625L of O2
46.08g 1 mol of C_2H_5OH 1 mol of $O_{2(g)}$ used
Excess of O2 = Original O2 – Used O2 = 105L – 65.625L = 39.4L of O2 left over

4. When 5.6 x 10^{24} particles of magnesium sulfide reacts with potassium hydroxide, then 500 g of precipitate forms. What is the percent error?

Mg =24.31
Ox2=32.00
Hx2= 2.02
58.33

G1 **R**

1) 1 $MgS_{(s)}$ + 2 $KOH_{(aq)}$ → 1 $K_2S_{(aq)}$ + 1 $Mg(OH)_{2(s)}$

5.6 E 24 particles **500g = AY**

(2) (3) (4)

5.6E24parts x1 mol of MgS x1mol of $Mg(OH)_{2(g)}$ x58.33 g $Mg(OH)_{2(s)}$ = .. of $Mg(OH)_2$(AY)

6.02E23parts 1 mol of C_2H_5OH 1 mol of $Mg(OH)_{2(g)}$

%error = (TY-AY)/TY x 100% = 500g/85.97.. x 100 = 58.15…% = 58.2 %

5. When 36.9 L of chlorine gas (SATP) reacts with 36.8 g of magnesium oxide, 38.9 g of magnesium chloride formed. What mass of magnesium chloride did you expect?(TY)

G1 G2 R

1) 2 $Cl_{2(g)}$ + 2 $MgO_{(s)}$ → 1 $O_{2(g)}$ + 2 $MgCl_{2(s)}$

36.9L 36.8g 38.9 g = AY

(2) (3) (4)

36.9L x 1 mol of Cl_2 x 2 mol of $MgCl_{2(s)}$ x 95.21 g of $MgCl_{2(g)}$ =70.831.. g of $MgCl_2$

24.8L 2 mol of Cl_2 1 mol of $MgCl_{2(s)}$ Cl_2 is excess

36.8g x 1 mol of MgO x x2mol of $MgCl_{2(s)}$ x 95.21 g of $MgCl_{2(g)}$= 86.919…g=86.9g of $MgCl_2$(TY)

40.31 g 2 mol of MgO 1mol of $MgCl_{2(g)}$ MgO excess

EXCESS LEFT OVER:

~~G1~~= E=R G2 = LR

1) 2 $Cl_{2(g)}$ + 2 $MgO_{(s)}$ → 1 $O_{2(g)}$ + 1 $MgCl_{2(s)}$

36.9L x 1 mol of Cl_2 x 2 mol of MgO x 24.8 L of $Cl_{2(g)}$=22.64…L of Cl_2 used

24.8L 2 mol of Cl_2 1mol of $Cl_{2(g)}$

Excess of Cl2 = Original – Used = 36.9L – 22.64…L= 14.3 L of Cl_2 left over.

6. When 24.5 g of iron(II) chloride reacts with 35.0 g of zinc, 7.2 g of iron was formed. What is the percent yield and percent error is this experiment?

G1=L ~~G2=E~~R used R

1 $FeCl_{2(aq)}$ + 1 $Zn_{(s)}$ → 1 $Fe_{(s)}$ + $ZnCl_{2(aq)}$

7.2 g = AY

(2) (3) (4)

G1: 24.5~~g~~x1 ~~mol of FeCl~~$_2$ x 1 ~~mol of Fe~~ x 55.85g of Fe = 10.79546… g of Fe (TY)

126.75~~g~~ 1 ~~mol of FeCl~~$_2$ 1 ~~mol of Fe~~ $FeCl_2$ is limiting

G2: 35.0gx1 mol of Zn x 1 mol of Fe x 55.85g of Fe = 29.8.. g of Fe

65.41g 1 mol of Zn 1mol of Fe Zn is excess

%yield = AY/TY x 100% = 7.2g/10.795…g x 100% = 66.7%

%error = (TY-AY)/TY x 100% = (10.7…g - 7.2g)10.7…g x100% = 33.3%

EXCESS LEFT OVER:

1 $FeCl_{2(aq)}$ + 1 $Zn_{(s)}$ → 1 $Fe_{(s)}$ + $ZnCl_{2(aq)}$

24.5~~g~~x1 ~~mol of FeCl~~$_2$ x 1 ~~mol of Zn~~ x 65.41g of Zn = 12.64… g of Zn used

126.75~~g~~ 1 ~~mol of FeCl~~$_2$ 1 ~~mol of Zn~~

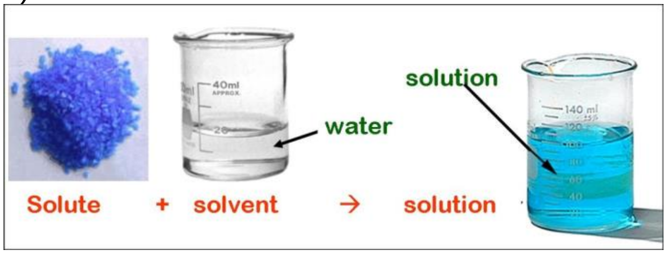
Excess Zn = Original – Used

Excess Zn = 35.0 g – 12.64…g = 22.4 g left over

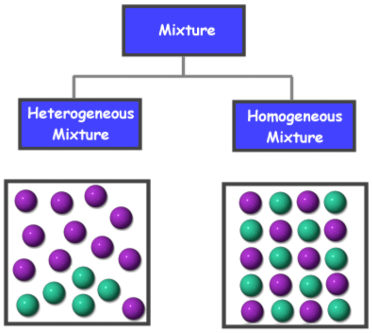
Worksheet 3.1 – Solution Terminology and Theory

1. Illustrate (with a drawing) the difference between:

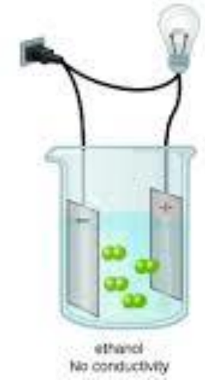
a) solute vs. solvent

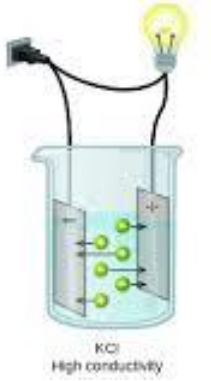


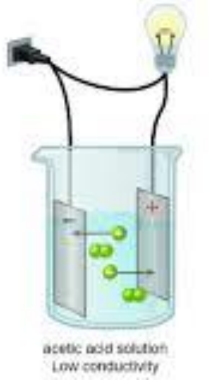
b) homogenous mixture vs. heterogenous mixture



c) electrolyte vs. non-electrolyte







2. Illustrate two factors that affect the rate of solubility.

1) Agitation
2) Temperature
3) Surface area

3. Illustrate how the following solids dissolve in water
   a) Glucose

   b) copper (II) sulphate

   c) hydrochloric acid

4. Many reactions only occur when the reactants are dissolved in water. Why?

Worksheet 2.2: Concentration Problems

1. What is the molar concentration of an electroplating solution in which 1.50 mol of copper (II) sulphate are dissolved in 2.00 L of water?

$C=\frac{n}{V}$; $C=\frac{1.50mol}{2.00L}$

C=0.750 mol/L

2. What is the molar concentration of a solution in which 0.240 mol of washing soda, sodium carbonate decahydrate, is dissolved in 480 mL of water to make soft water solution?

C=n/V; C=0.240 mol/0.480 L; C=0.500 mol/L

3. What is the molar concentration of 500 mL of a solution that contains 12.7 g of swimming pool chlorinator, $Ca(OCl)_2$?

1) n=m/M; n=12.7/142.98g/mol; n=0.0888…mol

2) C=n/V; C=0.0888…mol / 0.500L; C=0.178 mol/L

Ca = 40.08
Ox2 = 32.00
Clx2 =70.90
142.98g/mol

4. A given sample of household ammonia contains 156 g of ammonia dissolved in water to form a 2.00L solution. What is the molar concentration of the ammonia solution?

1) n=m/M; n=156g/17.04 g/mol; n=9.154…mol

2) **C=n/V; C=9.154…mol /2.00L; C=4.58 mol/L**

N = 14.01
Hx3=3.03
17.04 g/mol

5. Find the number of moles of sodium phosphate in 2.00L of a 0.100 mol/L sodium phosphate cleaning solution.

n=CV; n=0.100mol/L x 2.00 L; n=0.200mol

6. How many moles of potassium sulphate are there in 500 mL of a 0.242 M solution used to remove rust stains?

n=CV; n=0.242mol/L x 0.500L; n=0.121 mol

7. What mass of sodium bicarbonate must be added to a 2.50 L bowl to obtain a necessary 0.150 mol/L solution?

1) n=CV; n=0.150mol/L x 2.50L; n=0.375 mol
2) m=nM; m=0.375..mol x 84.01g/mol=31.5 g

Na = 22.99
H = 1.01
C = 12.01
Ox3=48.00
84.01 g/mol

8. What volume of a 0.075 mol/L solution would contain the necessary 1.10 mol of sodium phosphate used to remove radiator scales?

V=n/C; V=1.10mol/0.075 mol/L; V=15 L

9. What mass of sodium silicate is necessary to prepare 10.0 L of a 0.00500 mol/L water softening solution?

10. How many litres of 0.800 mol/L solution would contain 119.2 g of NaOCl?

1) n=m/M; n=119.2g/74.44g/mol; n=1.60…mol

2) V=n/C; v=1.60…mol/0.800mol/L; v=2.00 L

Na=22.99
O=16.00
Cl=35.45
74.44g/mol

Worksheet 2.3: Making solutions and dilutions

1. A scientist has a container with solid sodium hydroxide and a container of 5.00 mol/L sodium hydroxide.

   a) What are the two ways that the scientists can use to make a solution with a specific volume and concentration?

   Make a solution by mixing a solute of specific mass with a specific volume of solvent (water)

   OR make a dilution by adding water to a solution that is already made.

   b) What are two ways that the scientist can dilute the 5.00 mol/L solution?

   Evaporate the solvent and then remove some solute and add the solvent back OR add more solvent to a small portion of the solution.

2. Describe the steps you would take to make 100 mL of a 0.200 mol/L sodium chloride solution from salt crystals. Include the equipment and calculations you would make. Remember this is not a reaction.

   1) Calculate moles – n=CV; n=0.200 mol/L x 0.100 L; n=0.0200 mol Na=22.99
   2) Calculate mass – m=nM; m=0.0200mol x 58.44g/mol; m=1.17g Cl=35.45
   3) Weight with a scale; Mix in beaker with 50 mL of water. 58.44 g/mol
   4) Place solution in a 100 mL volumetric flask and fill to the meniscus/calibration line
   5) **Cap and mix**

3. Describe the steps you would take to make 250 mL of a 0.453 mol/L solution of copper (II) sulphate from solid copper (II) sulphate pentahydrate. Include equipment and calculations.

   1) Calculate the moles – n= CV; n=0.453 mol/L x 0.250 L; n=0.113…mol Cu=63.55

   2) Calculate the mass – m=nM; m=0.113…mol x 249.71g/mol; m=28.3g

   3) Wieght it; mix in beaker with about 125 mL
   4) Place in a 250 mL volumetric flask and fill to the meniscus/calibration line
   5) **Cap and mix**
   Equipment: Calculator, weight scale, 250 mL volumetric flask, 125 mL beaker, eye dropper, cap

4. Describe the steps you would take to **make** 100 mL**(V2)** of a 0.50 mol/L **(C2)** sucrose solution from a container of 2.10 mol/L**(C1)** sucrose solution. Include equipment and calculations.

   1) Calculate volume that needs to be removed. $V_1=C_2V2/C1$;
   V1=0.50mol/Lx0.100L/2.10mol/L
   V1=0.0238; V1=24mL
   2) Remove 24 mL with a graduated pipet
   3) Place in a 100 mL volumetric flask; fill to calibration line; cap and mix

5. Describe the steps you would take to make 500 mL**(V2)** of a 0.900 mol/L**(C2)** sulphuric acid from a 1.50 L**(V1)** container of 6.00 mol/L**(C2)** sulphuric acid solution. Include equipment and calculations.

   1) Calculate volume; V1=C2V2/C1; V1=0.900mol/L x 0.500L/6.00mol/L =0.0750L or 75.0 mL
   2) Remove 75 mL with a volumetric pipet.
   3) Place in a 500 mL volumetric flask; fill with 425ml of water to calibration line and cap and mix

6. What is the final concentration of a cleaner if 10 L(**V1)** of concentrated sodium hydroxide (19.1 mol/L)**C1)** is diluted to 400 L(**V2)**?
C2 = C1V1/V2;   19.1mol/L x 10 L / 400L = 0.48 mol/L

7. What is the mass of baking soda (sodium hydrogen carbonate) needed to make 2.5 L of a 1.00mol/L solution?
    1) **n=CV; 1.00 mol/L x 2.5 L; n=2.5 mol**
    2) **m=nM; 2.5mol x 84.01 g/mol; m=2.1 x 10^2 g or 0.21 kg**

8. If 2.0 L of water is added to 1.0 L of a 0.250 mol/L solution of potassium hydroxide what is the final concentration. (Be Careful)
C2=C1V1/V2; C2=0.250mol/L x 1.0L /3.0 L ; C2 = 0.083 mol/L

9. CHALLENGE: If 1.50 L of a 12.4 mol/L solution of hydrochloric acid was mixed with 300 mL of a 6.10 mol/L solution of hydrochloric acid, then what would be the final concentration.
Cnew=ntotal/Vtotal; Cnew = (1.50Lx12.4mol/L) + (6.10 mol/L x 0.300L)/ (1.50L + 0.300L)
Cnew=(18.6 mol + 1.83 mol)/1.8 L; Cnew = 11.4 mol/L

10. CHALLENGE: How much water is added to 50.0 mL**(V1)** of a 0.500 mol/L**(C1)** solution to make a 0.100 mol/L**(C2)** solution?
V2=C1V1/C2; V2=0.500mol/L x 0.050L/0.100mol/L; V2 = 250 mL

Vwater = V2-V1; Vwater = 250 ml – 50 mL; Vwater = 200 mL

Worksheet 2.4: Dissociation and ionization reactions

Name: _______

1. What type of compounds dissociate? What type of compounds ionize?
   Ionic **Acids & molecular gases**

2. Write dissociation or ionization reactions for the following chemicals after they are mixed with water. Show the physical states of all species involved. Use modified ionization reactions when necessary.

   a) Solid hydrochloric acid

   $HCl_{(s)} \xrightarrow{H2O(l} H+_{(aq)} + Cl-_{(aq)}$

   $HCl_{(s)} + H_2O_{(l} \rightarrow H_3O+_{(aq)} + Cl-_{(aq)}$

   b) Solid strontium hydroxide

   $Sr(OH)_{2(s)} \rightarrow Sr^{2+}_{(aq)} + 2OH^{-}_{(aq)}$

   c) Solid copper (II) sulphate pentahydrate

   $CuSO_4\ 5H_2O_{(s)} \rightarrow Cu^{2+}_{(aq)} + SO_4^{2-}_{(aq)} + 5H_2O_{(l)}$

   d) Solid sodium bicarbonate (hydrogen carbonate

   $NaHCO_{3(s)} \rightarrow Na^{+}_{(aq)} + HCO_3^{-}_{(aq)}$

   e) ammonia gas (acid and bases)

   $NH_{3(g)} + H_2O_{(l)} \rightarrow NH_4^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$

3. For each of the following write dissociation or ionization equations and find the concentration of each ion.

   a) 0.90 mol/L solution of sodium phosphate

   $Na_3PO_{4(s)} \rightarrow 3Na+_{(aq)} + PO_4^{3-}{}_{(aq)}$

   0.90mol/L **x 3mol of Na/1mol of Na_3PO_4 =2.7mol/L** **x 1mol of PO_4^{3-}/1mol of Na_3PO_4 =0.90mol/L**

   b) 0.143 mol/L solution of nitric acid

   $HNO_{3(aq)} + H_2O_{(l)} \rightarrow H_3O+_{(aq)} + NO_3^{-}{}_{(aq)}$

   =0.**143 mol/L** **=0.143 mol/L**

   c) 0.0135 mol/L solution of calcium hydroxide

   $Ca(OH)_{2(s)} \rightarrow Ca^{2+(}{}_{aq)} + 2OH^{-}_{(aq)}$

   0.0135mol/L

   =0.0135 mol/L **x=0.0270mol/L**

   d) 0.150 mol of hydrogen fluoride gas bubbled into 1.00 L of water

   $HF_{(g)} + H_2O_{(g)} \rightarrow H_3O^{+}{}_{(aq)} + F-_{(aq)}$

   0.150mol **0.150mol/L** **0.150mol/L**

4. What is the concentration of chloride ions in a solution prepared by dissolving 800 g of zinc chloride in 4.50 L of water?

1) n=m/M; n=800/136.28g/mol; n=5.87…mol

2) $ZnCl_{2(s)} \rightarrow Zn\ 2+_{(aq)} + 2Cl-_{(aq)}$

5.87 mol 11.74…mol

C=n/V; C=2.61mol/L

5. What is the mass of calcium chloride required to prepare 2.000 L of 0.120 mol/L chloride ions?

1) n=CV; -.120mol/L x 2.00L = 0.240mol

2)$CaCl_{2(s)} \rightarrow Ca2+_{(aq)} + 2Cl-_{(aq)}$

3) 0.240molx1mol/2mol

=0.120mol

4)m=nM; m=0.120mol x 110.98g/mol; 13.3 g

6. What is the final concentration if 2.0 L of ***water*** is added to 4.50 L of a 0.89 mol/L solution of sodium chloride?

C2=C1V1/V2; C2=0.89mol/L x 4.50L/6.50L; C2=0.62mol/L

Worksheet 4.5: Net Ionic Equations

For the following reactions, write the nonionic equation, the total ionic equation and the net ionic equation.

1. Aqueous solutions of sodium sulphate and barium bromide are mixed.
NON IONIC: $Na_2SO_{4(aq)} + Ba(Br)_{2(aq)} \rightarrow BaSO_{4(s)} + 2NaBr_{(aq)}$

TOTAL IONIC: $\cancel{2Na^{+}}_{(aq)} + SO_4{}^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} \; \cancel{2Br^{-}{}_{(aq)}} \rightarrow BaSO_{4(s)} + \cancel{2Na^{+}}_{(aq)} + \cancel{2Br^{-}}_{(aq)}$

NET IONIC: $SO_4{}^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} \rightarrow BaSO_{4(s)}$

2. A lead (II) nitrate solution reacts with sodium sulphide solution
NON IONIC: Pb(NO3)2 (aq) + Na2S(aq) → 2 NaNO3(aq) + PbS(s)

Total IONIC: $Pb\,^{2+}{}_{(aq)} + \cancel{2NO3^{-}{}_{(aq)}} + \cancel{2Na^{+}{}_{(aq)}} + S^{2-}{}_{(aq)} \rightarrow \cancel{2Na^{+}{}_{(aq)}} + \cancel{2NO3^{-}{}_{(aq)}} + PbS_{(s)}$

NET IONIC: $Pb\,^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} \rightarrow PbS_{(s)}$

3. Sulphuric acid is neutralized by a potassium hydroxide solution
NON IONIC: $H_2SO_{4(aq)} + 2KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + 2HOH_{(l)}$

TOTAL IONIC: $2H^{+}{}_{(aq)} + \cancel{SO_4{}^{2-}{}_{(aq)}} + \cancel{2K^{+}{}_{(aq)}} + 2OH^{-}{}_{(aq)} \rightarrow \cancel{2K^{+}{}_{(aq)}} + \cancel{SO_4{}^{2-}{}_{(aq)}} + 2HOH_{(l)}$

NET IONIC: $2H^{+}{}_{(aq)} + 2OH^{-}{}_{(aq)} \rightarrow 2HOH_{(l)}$

$H^{+}{}_{(aq)} + OH^{-}{}_{(aq)} \rightarrow HOH_{(l)}$

4. Hydrochloric acid is added to a solution of barium hydroxide

5. Magnesium metal is added to an aqueous solution of hydrogen bromide
NON IONIC: $Mg_{(s)} + 2HBr_{(aq)} \rightarrow H_{2(g)} + MgBr_{2(aq)}$

TOTAL IONIC: $Mg_{(s)} + 2H^{+}{}_{(aq)} + \cancel{2Br^{-}{}_{(aq)}} \rightarrow H_{2(g)} + Mg^{2+}{}_{(aq)} + \cancel{2Br^{-}{}_{(aq)}}$

NET IONIC: $Mg_{(s)} + 2H^{+}{}_{(aq)} \rightarrow H_{2(g)} + Mg^{2+}{}_{(aq)}$

6. Zinc reacts with copper (II) sulphate solution

7. Zinc reacts with acetic acid (vinegar)

NON IONIC: $Zn_{(s)} + 2CH_3COO\underline{H}_{(aq)} \rightarrow H_{2(g)} + Zn(CH_3COO)_{2(aq)}$

TOTAL IONIC: $Zn_{(s)} + \cancel{2CH_3COO^-_{(aq)}} + 2H^+_{(aq)} \rightarrow H_{2(g)} + Zn^{2+}_{(aq)} + \cancel{2CH_3COO^-_{(aq)}}$

NET IONIC: : $Zn_{(s)} + 2H^+_{(aq)} \rightarrow H_{2(g)} + Zn^{2+}_{(aq)}$

8. Bromine is added to a magnesium iodide solution

$Br_{2(l)} + MgI_{2(aq)} \rightarrow I_{2(s)} + MgBr_{2(aq)}$

$Br_{2(l)} \cancel{+ Mg^{2+}_{(aq)}} + 2I^-_{(aq)} \rightarrow I_{2(s)} \cancel{+ Mg^{2+}_{(aq)}} + 2Br^-_{(aq)}$

$Br_{2(l)} + 2I^-_{(aq)} \rightarrow I_{2(s)} + 2Br^-_{(aq)}$

Worksheet 2.6: Solution Stoichiometry

1. A 200 mL solution of potassium phosphate reacts with 100 mL of 0.150 mol/L iron (III) sulphate solution. What is the concentration of the potassium phosphate solution?

2. If 230 mL of a 1.00 mol/L solution of aluminium chlorate is reacted with sufficient lithium hydroxide solution, what mass of precipitate is formed?

$$\mathbf{Al(ClO_3)_{3\,(aq)} \quad + \quad 3LiOH_{(aq)} \quad \rightarrow \quad 3LiClO_{3(aq)} \quad + \quad Al(OH)_{3(s)}}$$

0.230L = V

1.00 mol/L = C

n=CV; n=1.00mol/Lx0.230L

0.230mol/1mol **x/1mol**

x=0.230mol

m=nM; m=0.230mol x 78.01g/mol

m=17.9 g

3. Predict the mass of magnesium metal that will be required to react with 44.0 ml of 0.200 mol/L hydrochloric acid.

4. What volume of 1.00 mol/L $HNO_{3(aq)}$ is required to react completely with 1.20g of $LiOH_{(aq)}$?

1) $HNO_{3(aq)}$ + $LiOH_{(aq)}$ → $LiNO_{3(aq)}$ + $HOH_{(l)}$

2) V=? n=1.20g/23.95g/mol

V n=0.050104mol

3) X/1mol = 0.050104…mol/1mol

X=0.050104…mol

4) V=n/C; V=0.050104…mol/1.00mol/L

V=0.0501L or 50.1 mL

5. A 100 ml sample of sodium sulphide solution is completely reacted with 50.0 ml of 0.250 mol/L lead (II) nitrate solution. Predict the concentration of the $Na_2S_{(aq)}$?

6. 500 ml of 0.150 mol/L cobalt (II) nitrate solution is reacted with 500 ml of 0.250 mol/L of sodium hydroxide solution producing 4.77 g of precipitate. Find the % yield for this reaction.

$Co(NO_3)_{2(aq)}$	+	$2NaOH_{(aq)}$	→	$2NaNO_{3(aq)}$	+	$Co(OH)_{2(s)}$
n=CV		**n=CV**				**n=m/M**
n=0.150mol/Lx0.500L		**n=0.250mol/Lx0.500L**				**n=4.77g/92.95g/mol**
n=0.075mol		**n=0.125mol**				**n=0.0513…mol**
0.075mol/1mol	**=**	**x/2 mol**				
		x=0.150mol				
		0.125 < 0.150 LIMITING				
		0.125mol/2mol			**=**	**x/1mol**
						x=0.0625 (5.809..g)

% yield = A/T x 100;   % yield = 0.0513…mol/0.0.0625 mol x 100;   % yield = 82.1%

7. CHALLENGE: Predict the final mass of a 500 g bar of lead that is allowed to react completely with 2.00 L of 2.00 mol/L HCl.

$Pb_{(s)}$	+	$2HCl_{(aq)}$	→	$H_{2(g)}$	+	$PbCl_{2(s)}$
500g		**n=CV**				
		n=2.00mol/L x 2.00L				
		n=4.00mol				
x/1mol =		**4.00mol/2mol**				
x=2.00mol						

m=nM; m=2.00mol x 207.19g/mol; m=414.38 g

mfinal = 500 – 414.38 = 85.6 g

8. A 75.0 mL sample of 0.25 mol/L silver chlorate solution reacts with 19.0 mL of 0.50 mol/L copper (II) sulphate solution. What is the concentration of the solution produced? (NOTE: Find out what the **total** volume of the solution produced.)

1) $2AgClO_{3(aq)} + CuSO_{4(aq)} \rightarrow Cu(ClO_3)_{2(aq)} + Ag_2SO_{4(s)}$

2) n=CV   n=CV   C=?

n=0.25mol/Lx0.075L   n=0.50mol/Lx0.019L

n=0.01875 mol   n=0.0095 mol

0.01875/2mol = x/1mol

x=0.009375…mol

0.0095>0.009375…mol EXCESS

0.01875/2mol = x/1mol
x=0.009375…mol

C=n/V;

C=0.009375mol/0.094L

C=0.0997; C=0.10 mol/L

Worksheet 2.7: Review of Solutions

1. Answer the following questions
   a) How do solutions differ from heterogeneous mixtures?
      Solutions are uniform and appear as one substance – heterogenous do not.

   b) How do the number of molecules of $C_{12}H_{22}O_{11}$ in 250 mL of a 1.5 mol/L solution of $C_{12}H_{22}O_{11}$ compare to the number of molecules of $C_6H_{12}O_6$ in 250 mL of a 1.5 mol/L $C_6H_{12}O_6$?
      The number of molecules is the same (n=CV); the mass is different

   c) What is the term used to describe two liquids which will **NOT** mix with each other?
      immiscible

   d) What are two factors that affect the amount of solute that dissolves and two factors that affect the rate of dissolving? **Amount: temperature, pressure Rate: temperature, surface area, agitation**
2. Write the equation for each of the following dissolving in water. Use modified Arhenius theory.
   a) Hydrogen chloride gas
      $HCl_{(g)} + H_2O_{(g)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$*IONIZE*

   b) Solid aluminum nitrate
      $Al(NO_3)_{3(s)} \rightarrow Al^{3+}_{(aq)} + 3NO_3^-{}_{(aq)}$ DISSOCIATE

   c) Solid sucrose
      $C_{12}H_{22}O_{11(s)} \rightarrow C_{12}H_{22}O_{11(aq)}$ DISSOLVE

   d) Aqueous nitric acid
      $HNO_{3(aq)} + H_2O_{(g)} \rightarrow H_3O^+_{(aq)} + NO_3^-{}_{(aq)}$*IONIZE*

3. Determine the concentration of each of the following solutes in the solution described.
   a) 0.725 mol of cobalt (II) nitrate in 1.35 L of solution.
      C=n/V; C=0.725mol/1.35L; C=0.537 mol/L

   b) 15.0 g of barium sulphate in 125 mL of solution. **Ba=137.33**
      n=m/M; n=15.0g/233,39g/mol; n=0.0642…mol S=32.06

      C=n/V; C=0.065…mol/0.125L; C=0.514mol/g Ox4=64.00/233.39g/mol

   c) 1.85×10^{22} molecules of ammonia gas in 400 mL of solution.
      n=p/P; n=1.85×10^{22} /6.02×10^{23}; n=0.0307..mol

      C=n/V; C=0.0307…mol/0.400L; C=0.0768 mol/L

4. Write the dissociation equation and calculate the concentration of each of the ions produced in 1.25 mol/L solution of barium chloride.

   $BaCl_{2(s)} \rightarrow Ba^{2+}_{(aq)} + 2Cl^-_{(aq)}$

   1.25mol/L/1mol= x/1mol = x/2mol

   x=1.25 mol/L x=2.50 mol/L

5. Write the dissociation equation and determine the concentration of the solution if 1.26 mol/L of $[Na^+]$ is found in a sodium phosphate solution.

$Na_3PO_{4(s)}$ → $3Na^+_{(aq)}$ + $PO_4^{3-}{}_{(aq)}$

X/1mol **= 1.26 mol/L/3mol**

x=0.420mol/L

6. CHALLENGE: What is the [Cl^-] in a solution made by mixing 200 mL of 0.300 mol/L sodium chloride solution with 350 mL of 0.250 mol/L calcium chloride solution?

$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$ $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$C=ntotal/Vtotal

n=CV; n=0.300mol/Lx0.200L n=CV; n=0.250mol/Lx0.350L C=0.235mol/0.550L
n=0.0600mol/1mol=x/1mol n=0.0875mol/1mol = x/2mol C=0.427 mol/L
x=0.0600mol x=0.175 mol

Write net ionic equations for the following reactions. (3 marks)

a) lead nitrate solution is mixed with sodium hydroxide

$Pb(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow 2NaNO_{3(aq)} + Pb(OH)_{2(s)}$

$Pb^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \rightarrow 2Na^+_{(aq)}\ 2NO_3^-{}_{(aq)} + Pb(OH)_{2(s}$

$Pb^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Pb(OH)_{2(s)}$

b) barium nitrate reacts with potassium sulphide

$Ba(NO_3)_{2(aq)} + K_2S_{(aq)} \rightarrow 2KNO_{3(aq)} + BaS_{(aq)}$

$Ba^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2K^+_{(aq)} + S^{2-}_{(aq)} \rightarrow 2K^+_{(aq)} + 2NO_3^-{}_{(aq)} + Ba^{2+}_{(aq)} + S^{2-}_{(aq)}$

NO NET IONIC EQUATION

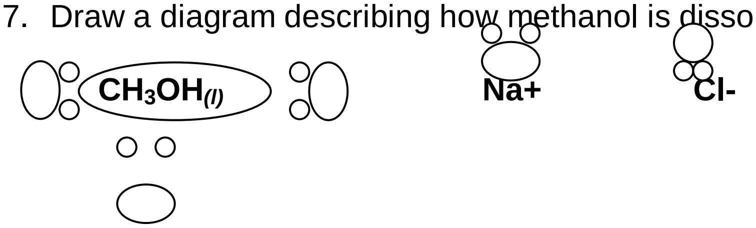
c) nitric acid reacts with barium hydroxide

$2HNO_{3(aq)} + Ba(OH)_{2(aq)} \rightarrow Ba(NO_3)_{2(aq)} + 2HOH_{(l)}$

$2H^+_{(aq)} + 2NO_3^-{}_{(aq)} + Ba^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ba^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2HOH_{(l)}$

$H_{(aq)} + OH_{(aq)} \rightarrow HOH_{(l)}$ (Don't forget to reduce)

7. Draw a diagram describing how methanol is dissolved in water. (1 mark)



8. Predict whether the following solutes are electrolytes or nonelectrolytes:
   a) nitrogen monoxide – **nonelectrolyte (molecular)**
   b) hydrofluoric acid – **electrolyte (acid)**
   c) magnesium hydroxide – **nonelectrolyte (ionic BUT not aqueous)**
   d) potassium hydrogen carbonate – **electrolyte (ionic & aqueous)**

9. A scientists wants to make 100 mL of a 0.150 mol/L sodium hydroxide solution. He has 100 g of solid sodium hydroxide and he has 1.00 L of a 2.25 mol/L sodium hydroxide solution. Describe step by step the two ways that he could make his 0.150 mol/L solution. Include the sample calculations and equipment.

Method I - from solid	**Method II - dilution**
1) Find moles; n=CV; 0.150x0.100=0.0150	**1) Find volume; $V_1=C_2V_2/C_1$=0.150x0.100/2.25=6.67ml**
2) Find mass: m=nM; 0.0150x40.00=0.600g	**2) Remove 6.67mL with a graduated pipet**
3) Weigh on a scale	**3) Place in a 100 mL volumetric flask and fill to line**
4) Mix 0.600g in 50 ml of water	**4) Cap and mix**
5) Place in 100 mL volumetric flask and fill to calibaration line. Cap and mix	

10. A 20.0 g sample of lead (II) nitrate is mixed in 1.00 L of water. The lead (II) nitrate solution then reacts with a 1.00 L of a 0.100 mol/L solution of rubidium iodide. If 20.0 g of precipitate forms, what is the percent yield?

Worksheet 2.8: Introduction to Acids & Bases

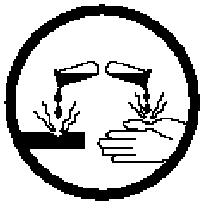
1. Safety is very important when working with acids. Describe what the student should do in the following situations.
   a) A student drops a 100 mL beaker with 50 mL of hydrochloric acid and spills the acid onto the floor.
   Report the accident to a teacher. Place baking soda until it stops bubbling. (If you have no baking soda, dilute the acid with water.)

   b) A student drips a couple of drops of sodium hydroxide solution onto his hand.
   Report the incident to a teacher. Wash the sodium hydroxide off with cold water.

   c) A beaker with $Ba(OH)_2$ tips over onto the lab bench.
   Report the incident to a teacher. Place vinegar (acetic/ethanoic acid) onto the base. (If you have no vinegar, dilute the base with water.)

   d) A student would like to dilute an acid and would like to know if he should add the acid to the water or the water to the acid
   Always add acid to water (A to W).

2. WHMIS symbols help communicate dangers.
   a) WHMIS stands for **<u>Workplace Hazardous Materials Information System</u>**
   b) The symbol that would be associated with a beaker of base that corrodes metal is

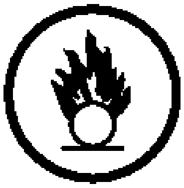


Corrosive material

   c) Acids and bases can cause immediate and serious damage to a person's skin. The WHMIS symbol related to this is

Material causing immediate and serious toxic effect

   d) Some acids react with oxygen. The WHMIS symbol found on a bottle of this acid would be



Oxidizing Material

3. A person would like to make 100 mL 1.00 mol/L solution of NaOH. Describe the steps the student would use. Include the calculations.
   1) **Calculate the moles: n=CV; n=1.00mol/L x 0.100L; n=0.100mol**
   2) **Calculate mass: m=nM; m=0.100mol x 40.00g/mol; m=4.00g**
   3) **Weigh with scale; mix in beaker with 50 mL of water.**
   4) **Place in 100 mL volumetric flask, fill to calibration line, cap & mix.**

4. A person would like to dilute a 12.1 mol/L solution of HCl and make a 250 mL 3.00 mol/L solution. Describe the steps the student would use. Include the calculations.
   1) **Find the volume; v1=C2V2/C1; V1=3.00mol/Lx 0.250L/12.1mol/L: V=62.4mL**
   2) **Remove it with graduated pipet.**
   3) **Place in 250 mL volumetric flask; fil to calibration line; cap & mix**

5. Indicators change color to indicate whether you have an acid or base. Litmus paper and bromothymol blue are two common indicators. Complete the following table for these indicators.

PH	**Litmus Paper color**	**Bromothymol Blue color**
3	**Red**	**yellow**
7	**No change**	**Green**
10	**Blue**	**Blue**

6. What is one property that is similar between acids and bases?
   Both electrolytes, both dissolve in water (aqueous)

7. What is one property that is different between acids and bases?
   PH, taste, touch, reactions

8. Complete the following acid or base reactions.
   a) sulphuric acid is neutralized by potassium hydroxide. Identify the "salt" in the reaction.
      $\mathbf{H_2SO_{4(aq)} + 2KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + 2HOH_{(l)}}$

      salt

b) hydrochloric acid reacts with magnesium

$\mathbf{2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}}$

salt

c) self ionization of water

$\mathbf{H_2O_{(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + OH^-_{(aq)}}$ **OR** $\mathbf{H_2O_{(g)} \rightarrow H^+_{(aq)} + OH^-_{(aq)}}$

No salt

Worksheet 2.9: Acid & Base Calculations

1. A 1.00 L solution of 1.50 mol/L perchloric acid is dilluted by adding 500 mL *of water*. What is the hydronium concentration of the dilluted solution? **V2= V1 + Vwater=1.00L + 0.500L**

   $\mathbf{HClO_{4(aq)} + H_2O_{(g)} \rightarrow H_3O^{+}_{(aq)} + ClO_{4}^{-}{}_{(aq)}}$

   C2=C1V1/V2
   C2=1.50mol/Lx1.00L/1.50L
   C2=1.00mol/L 1.00mol/L/1mol = X/1mol
   X=1.00mol/L

2. A 250mL solution of 3.56 mol/L barium hydroxide is sitting on the counter in the lab. Help a chemistry 20 student determine the hydronium concentration of the solution.

   $\mathbf{Ba(OH)_{2(s)} \rightarrow Ba2+_{(aq)} + 2OH-_{(aq)}}$

   n=CV; n=3.56 x 0.250 = 0.89 mol
   X 2mol/1mol =1.78mol
   C = n/V; C = 1.78mol/0.250L = 7.12mol/L
   H3O+ = Kw/[OH-]; H3O+ = 1E-14/7.12
   = 1.40E-15 mol/L

3. A 1.00 mol/L solution of nitric acid ionizes. What is the hydroxide ion concentration?

   $\mathbf{HNO_{3(aq)} + H_2O_{(g)} \rightarrow H_3O^{+}_{(aq)} + NO_{3}^{-}{}_{(aq)}}$

   1.00 mol/L X1/1mol; X=1.00 mol/L

   [OH-] = kw/[$\mathbf{H_3O^{+}_{(aq)}}$**]**

   = $\mathbf{1.00 \times 10^{-14}(mol/L)^2/1.00mol/L}$**; [OH-] =** $\mathbf{1.00 \times 10^{-14}mol/L}$

4. A student takes 11.6 grams of strontium hydroxide and adds it to 3.00 litres of water. What is the hydronium concentration?

5. A solution contains 1.67×10^{-14} mol/L of hydronium ions. Determine the mass of barium hydroxide that was added to 1.00 L of water to make this solution.

   $\mathbf{Ba(OH)_{2(s)} \rightarrow Ba2+_{(aq)} + 2OH-_{(aq)}}$ **[OH-] = kw/[** $\mathbf{H_3O^{+}_{(aq)}}$**]**

   = $\mathbf{1.00 \times 10^{-14}(mol/L)^2/1.67 \times 10^{-14}mol/L}$

   X1mol/2mol 0.5988…mol/L

   X=0.2994…mol/L

   n=CV; n=0.2994 x 1L=0.2994…mol

   m=nM; m= 0.2994…mol x 171.35 g/mol

   m=51.3 g

6. What is the concentration of hydroxide ions found in a 1.00 L solution of 2.00 mol/L potassium hydroxide?

7. What is the hydroxide concentration of a 1.00 L solution of 2.50 mol/L hydrobromic acid?

$HBr_{(aq)} + H_2O_{(g)} \rightarrow H_3O^+_{(aq)} + Br^-_{(aq)}$

2.50 mol/L x 1mol/1mol

X=2.50 mol/L

[OH-] = kw/[$H_3O^+_{(aq)}$]

= $1.00 \times 10^{-14}(mol/L)^2/2.50 mol/L$

[OH-] = 4.00×10^{-15}mol/L

8. What is the hydronium concentration when 1.00 mol/L of barium hydroxide dissociates

9. 6.02 x 10^{22} particles of sulphuric acid ionize into hydrogen sulphate ions in 1.00 L of water. What is the hydroxide concentration of the solution?

$H_2SO_{4(aq)} + H_2O_{(g)} \rightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$

n=p/P

n=6.02 x 1022/6.02 x 1023

n=0.1…mol

C=n/V = 0.1…mol/1.00L

0.100mol/L x 1mol/1mol; X=0.100 mol/L

[OH-] = kw/[$H_3O^+_{(aq)}$]

= $1.00 \times 10^{-14}(mol/L)^2/0.100 mol/L$;

[OH-] = 1.00×10^{-13}mol/L

10. A solution contains 3.45 x 10^{-12} mol/L of hydroxide ions. What is the concentration of the hydrochloric acid solution that contain these hydroxide ions?

Worksheet 2.10: Acid & Base Review

1. The concentration of hydroiodic acid is 1.73 x 10^{-3} mol/L. What is the pH and the pOH?

   $HI_{(aq)} + H_2O_{(g)} \rightarrow H_3O^+_{(aq)} + I^-_{(aq)}$

   1.73 x 10-3 mol/L/1mol = X/1mol

   X=1.73 x 10-3 mol/L

   PH = -log (1.73 x 10-3 mol/L)

   PH = 2.76195…. (2.762)

   POH = 14-pH = 11.238

2. What is the hydronium concentration and hydroxide concentration of a 2.47 x 10^{-2} mol/L solution of thallium hydroxide?

3. Complete the following table (Significant digits are important):

pH	$[H^+]$ or $[H_3O+]$	$[OH^-]$	pOH	A/B/N
14 -4.56 **OR** **-log(3.6E-10)** **= 9.44**	**1E-14/2.8E-5 =3.6E-10mol/L** **OR** **$10^{-9.44}$**	**$=10^{-4.56}$ = 2.8E-5mol/L** **OR** **1E-14/3.6E-5**	4.56	**B**
2) 14-4.910 =9.090	**8.13 x 10^{-10}mol/L**	1.23 X 10^{-5}	**-log (1.23E-5) =4.910**	**B**
3) 7.449	3.56 x 10^{-8}	**2.81 x 10^{-7}mol/L**	**6.551**	**B**
4) 12.8	**2 x 10^{-13}mol/L**	**6. x 10^{-2}mol/L**	**1.2**	**B**
5) 3.52	**3.0 x 10^{-4}**	**3.3 x 10^{-11}**	**10.48**	**A**
6) 13.759	**1.74 x 10^{-14}**	5.74 X 10^{-1}	**0.241**	**B**

pH	$[H^+]$ or $[H_3O+]$	$[OH^-]$	pOH	A/B/N
7) 6.55	**2.8×10^{-7}**	**3.5×10^{-8}**	7.45	**A**
8) 2.399	$3.99 X 10^{-3}$	**2.51×10^{-12}**	**11.601**	**A**
9) 12.77	**1.7×10^{-13}**	**5.9×10^{-2}**	1.23	**B**
10) 5.95	**1.1×10^{-6}**	$8.9 X 10^{-9}$	**8.05**	**A**

4. What color would the indicator be given the following data:

	ORANGE IV	**METHLY RED**	**PHENOL RED**	**METHYL ORANGE**	**INDIGO CARMINE**
pOH=9.00 **pH = 5.00**	yellow	Red + Yellow = orange	yellow	yellow	blue
pH=8.3	Yellow	Yellow	Red	Yellow	Blue
[H+]=9.5 x 10^{-4} pH = 3.02	Yellow	Red	Yellow	Red	Blue
[OH-]=5.6 x 10^{-3} pOH = 2.25; pH = 11.75	Yellow	yellow	Red	Yellow	Blue + yellow = green
[H_3O+] =1.0 x 10^{-7}	Yellow	Yellow	Yellow to red = orange	Yellow	Blue

Worksheet 2.11: Introduction to Gases & Dalton's Gas Law

1. What are three physical properties of all gases?

Gases are do not have a fixed volume or shape (fill container), are compressible and diffuse.

2. What three variables affect gases?

Pressure, temperature and volume

3. What instrument measures pressure?
Barometer (manometer)

4. What is the SI unit for pressure?
KPa (kiloPascals)

5. What unit expresses the average kinetic energy of a gas?
Kelvin or degrees Celcius

6. A 1.00 L bottle of gas contains oxygen at 10.0 kPa, nitrogen at 12.1 kPa and hydrogen at 97.5 kPa

a. What is the total pressure?

$P_T = P_1 + P_2 + P_3$

$P_T = 10.0\text{ kPa} + 12.1\text{ kPa} + 97.5\text{ kPa}$

$P_T = 119.6$ kPa (one decimal place for significant digits)

b. What percent of each gas is present? (HINT % = P_{gas}/P_{total} x 100)

oxygen = 8.36 %; nitrogen = 10.1 %; hydrogen = 81.5 % (3 significant digits)

c. What is the volume of each gas?

V of oxygen =1.00L x 0.0836 = 0.0836 L = <u>83.6 mL</u>

7. Four gases (A,B,C and D) make up a mixture with a pressure of 150 kPa. What is the partial pressure of gas A, if gas B has a pressure of 58.0 kPa, gas C has a pressure of 23.8 kPa and gas D has a pressure of 15.9 kPa.

$P_1 = P_T - (P_2 + P_3 + P_4)$

P=150kPa – (58.0kPa + 23.8kPa + 15.9kPa)

<u>P=52.3 kPa</u>

8. Three gases make up a mixture. At a particular pressure, the partial pressures are measured: Gas A = 67.00 kPa, Gas B, 6.70 kPa, and Gas C = 0.67 kPa. What is the pressure conditions under which this measurement is taken?

P_T=P_1 + P_2 + P_3

P = 67.00 kPa + 6.70 kPa + 0.67 kPa = <u>74.37 kPa</u>

Worksheet 2.12: Boyles' Gas Law

1. What is the pressure when: (temperature is constant)

   a. 130 mL of a gas at 740 mmHg is changed to 150 mL?

   $P_2 = P_1V_1/V_2$; P_2=740mmHg x 130mL / 150mL

   P_2=641 mmHg

   b. 25 mL of gas at 65 atm is changed to 30.0 mL?

   $P_2 = P_1V_1/V_2$; P_2=65atm x 25mL / 30.0mL

   P_2=54 atm

   c. 1.0 L of gas at 70 kPa is changed to 1.2 L?

   $P_2 = P_1V_1/V_2$; P_2=70kPa x 1.0L / 1.2L

   P_2=58 kPa

2. What is the volume when: (temperature is constant)

   a. 75 mL of gas at 4.1 atm is changed to 7.0 atm?

   $V_2 = P_1V_1/P_2$; V_2=4.1atm x 75mL / 7.0atm

   V_2=44 mL

   b. 60.0 mL of gas at 760 mmHg is changed to 10 mmHg?

$V_2 = P_1V_1/P_2$; V_2=760mmHg x 60mL / 10 mmHg

V_2=<u>4.6L or 4.6 x 10^3 mL</u>

c. 400.0 mL of gas at 760 kPa is changed to 300 kPa?

$V_2 = P_1V_1/P_2$; V_2=760kPa x 400ml/300kPa

V_2=1013.33 mL; <u>1.01 x 10^3 mL or 1.01 L</u>

Worksheet 2.13: Charles' Gas Law

1. What is the volume when: (pressure is constant)

   a. 125 mL of gas at 25° C is cooled to Standard temperature?

   T_1=25 + 273.15=298.15K **T_2=0 + 273.15=273.15K**

   $V_2 = V_1T_2/T_1$; V_2=

   V_2=<u>0.11L or 1.1x102 mL</u>

   b. 300.0 mL of gas at 0.0°C is heated to 30.0°C?

   T_1=0 + 273.15=273.15K **T_2=30 + 273.15=303.15K**

   $V_2 = V_1T_2/T_1$; V_2=

   V_2=<u>0.333L or 333mL</u>

   c. 220.0 mL of gas at 10.0°C is heated to 100.0°C?

   T_1=10 + 273.15=283.15K **T_2=100 + 273.15=373.15K**

   $V_2 = V_1T_2/T_1$; V_2=

   V_2=<u>0.290L or 290 mL</u>

2. What is the temperature when: (pressure is constant)

   a. 30.0 mL (V1) of gas at 14°C (T1) is compressed to 22 mL (V2)?

   T_1=14 + 273.15=287.15K

   $T_2 = V_2T_1/V_1$; T_2=22mLx287.15/30mL

   T_2=210.6 K; <u>2.1 x 10^2K or -63C</u>

b. 16.4 mL of gas at 28°C is expanded to 20.0 mL?

T_1=28 + 273.15=301.15K

T_2 = V_2T_1/V_1; T_2=20 x 301.15 / 16.4

T_2=367.25K; <u>3.7x10^{2}K or 94C</u>

c. 39 mL of gas at 0.0°C is compressed to 35 mL?

T_1=0 + 273.15=273.15K

T_2 = V_2T_1/V_1; T_2=35x273.15/39

T_2=245.1K<u>; 2.5 x10^{2}K or -28C</u>

Worksheet 2.14: Lusac's Gas Law

1. What is the pressure when: (volume is constant)

   a. a gas at 130 C and 740 mmHg is changed to 150 C?

      T_1=273.15 + 130 = 403.15K T_2=273.15 + 150 = 423.15K

      P_1=$P_2$$T_1$/$T_2$; P_1=740mmHg x 403.15K / 423.15K

      P_1=777 mmHg

   b. a gas at 25 C and 65 atm is changed to 30.0 C?

      T_1=273.15 + 25 = 293.15K T_2=273.15 + 30.0 = 303.15K

      P_1=$P_2$$T_1$/$T_2$; P_1=

      P_1=66 atm

   c. a gas at 1.0 K and 70 kPa is changed to 1.2 K?

      P_1=$P_2$$T_1$/$T_2$; P_1=

      P_1= 84 kPa

2. What is the temperature in degrees Celcius when: (volume is constant)

   a. a gas at 75.0 C and 4.10 atm is changed to 7.00 atm?

      T_1=273.15 +75.0 = 348.15K

      T_2=$P_2$$T_1$/$P_1$; T_2=7.00 x 348.15/4.10

      T_2=594 K or 321C

b. a gas at 60.0 C and 760 mmHg is changed to 10.0 mmHg?

T_1=273.15 +75.0 = 348.15K

$T_2=P_2T_1/P_1$; T_2=

T_2=<u>4.38K or –269 C</u>

c. a gas at 113 K and 760 kPa is changed to 300 kPa?

$T_2=P_2T_1/P_1$; T_2=300kPa x 113K / 760kPa

T_2=<u>44.6K or –229 C</u>

Worksheet 2.15: Combined Gas Law

Solve the following gas problems.

1. If 120 mL of oxygen is collected at 27°C and 740 mmHg , what will the volume of the dry gas be at STP? **T=0C, P=760 mmHg**

   T_1=273.15 + 27 = 300.15 K, V_1=0.120L, P_1=740mmHg

   T_2=273.15 + 0 = 273.15 K, V_2=?, P_2=760mmHg

   $P_1V_1T_2=P_2V_2T_1$; V_2=

   V_2=0.11L or 1.1 x 10^2 mL

2. If 500.0 mL of hydrogen is collected at 293.15 K and 95.0 kPa, what will the volume of the gas by at SATP? **T=25C, P=100 kPa**

   T_1=293.15 K, V_1=0.500L, P_1=95.0kPa

   T_2=273.15 + 25 = 298.15 K, V_2=?, P_2=100kPa

   $P_1V_1T_2=P_2V_2T_1$; V_2=

   V_2=0.483L or 483 mL

3. 113 mL of oxygen is collected at 22°C and 98.0 kPa and left over night. The next day, the volume was 109 mL and the temperature was 21°C. What was the pressure?

   T_1=273.15 + 22 = 295.15 K, V_1=0.113L, P_1=98.0kPa

   T_2=273.15 + 21 = 294.15 K, V_2=0.109L, P_2=?

   $P_1V_1T_2=P_2V_2T_1$; P_2=

   P_2=101.25 kPa, P_2=1.0 x 10^2 kPa

4. 36 mL of nitrogen was collected at 25°C, but the barometer was broken so the pressure could not be read. Three days later, the new barometer arrived. The new volume was 32 mL, the temperature was 21°C and the pressure reading was 739 mmHg. What was the original pressure?

T_1=273.15 + 25 = 298.15 K, V_1=0.036L, P_1=?

T_2=273.15 + 21 = 294.15 K, V_2=0.032L, P_2=739mmHg

$P_1V_1T_2=P_2V_2T_1$

P_1=665.8 mmHg, $\underline{P_1 = 6.7 \times 10^2 \text{ mmHg}}$

5. If 250 mL of helium was collected at STP, what will the temperature be if the volume is reduced to 200 mL and the pressure increased to 110 kPa?

T_1=273.15 + 0 = 273.15 K, V_1=0.250L, P_1=101.325 kPa

T_2=?, V_2=0.200L, P_2=110 kPa

$P_1V_1T_2=P_2V_2T_1$; T_2=110kPa x 0.200L x 273.15K/(101.325kPa x0.250L)

$\underline{T_2\text{=237 K or -35.9 C}}$

6. A certain 1.0L sample of gas has a temperature of 23°C and a pressure of 0.96 atm. The sample was left overnight and the next day had a pressure of 1.00 atm and a volume of

1.1 L. What is the temperature on the second day?

T_1=273.15 + 23 = 296.15 K, V_1=1.0L, P_1=0.96 atm

T_2=?, V_2=1.1L, P_2=1.00 atm

$P_1V_1T_2$=$P_2V_2T_1$; T_2 = 1.1L x 1.00 atm x 296.15K/(0.96atm x 1.0 L)

T_2=339 K; $\underline{T_2=3.4 \text{ x } 10^2 \text{ K or } 66 \text{ C}}$

Worksheet 2.16: Ideal Gas Law

Solve the following gas problems.

1. What pressure (kPa) is exerted by 1.0 mol of an ideal gas contained in a 1.0 L vessel at 0.0°C?

   PV=nRT; P=1.0mol x 8.314LkPa/Kmol x 273.15K / 1.0 L

   P=2270.969 kPa, P=2.3 x 10^3 kPa

2. What volume will 5.0 mol of an ideal gas occupy at 25.0°C and 1.5 atm of pressure?

   V=nRT/P; V=5.0mol x 0.0821Latm/Kmol x 298.15 K / 1.5 atm

   V=81.59L; V=82L

3. Calculate the molar mass of gas if 4.5 L of the gas is at 785 mmHg, 23.5°C and the gas has a mass of 13.5 g.

   n=PV/RT; n=785mmHg x 4.5L / (62.4LmmHg/Kmol x 296.65 K)

   n=0.1915755…mol

   M=m/n; M=13.5g / 0.19…mol; M=70.74gmol or 71g/mol

4. 0.453 mol of a gas confined to a 15.0 L container exerts a pressure of 1.24 atm on the walls of the container. What is the temperature of the gas?

T=PV/nR; T=1.24atm x 15.0L / (0.453mol x 0.0821Latm/Kmol)

<u>T=500K or 227C</u>

5. 5.4 g of carbon dioxide gas is confined to a 20.0 L container at a temperature of 315.5 K. What pressure (kPa) does the gas exert?

n=m/M; n=5.4g/44.01g/mol; n=0.122699…mol

P=nRT/V; P=0.12…mol x 8.314LkPa/Kmol x 315.15K/20.0L

P=16.09 kPa; <u>P=16 kPa</u>

6. 2.125 g of a gas in a 1.25 L container exerts a pressure of 86.0 kPa at 40.0^{o}C. What is the molar mass of the gas?

n=PV/RT; n=86.0kPa x 1.25L / (8.314LkPa/Kmol x 313.15K)

n=0.041290…mol

M=m/n; M=2.125g/0.041290…mol; M=51.465 g/mol

M=<u>51.46g/mol or 51.5 g/mol</u>

7. To what temperature must 10.0 g of ammonia gas have to be heated in a 15.0 L container in order for it to exert a pressure of 3.50 atm?

n=m/M; n=10.0g / 17.04g/mol; n=0.5868…mol
T=PV/nR; T=3.50atm x 15.0L / (0.5868…mol x 0.0821Latm/Kmol)

T=1089.6 K; <u>T=1.09x10^{3}K</u>

8. 2.0×10^{-5}g of hydrogen gas at 327 K exerts a pressure of 50.5 kPa on the walls of a small tube. What is the volume of the tube?

n=m/M; n=m/M; n=2.0x10^{-5}g / 2.02g/mol; n=9.9… x 10^{-6} mol

V=nRT/P; V=9.9…x10^{-6}mol x 8.314LkPa/Kmol / 50.5kPa

V=5.3 x 10^{-4} L

Worksheet 2.17: Gas Stoichiometry

1. What mass of propane from a tank can be burned using 50 L of oxygen at STP?

Step 1) $C_3H_{8(g)}$ **+** $5O_{2(g)}$ → $3CO_{2(g)}$ **+** $4H_2O_{(g)}$

Step 2) *?* **n=PV/RT or n=v/V**

n=50L/22.4L/mol; n=2.3…mol

Step 3) X/1mol = 2.3…mol/5mol

X=0.44…mol

Step 4) m=nM; m=0.44…mol x 44.11g/mol

m= 19.69 g; m=20g

2. Hydrogen gas is burned in pollution-free vehicles to produce water vapor. What volume of hydrogen at 40^{o}C and 150 kPa can be burned using 300 L of oxygen gas measured at the same conditions?

Step 1) $2H_{2(g)}$ **+** $O_{2(g)}$ → $2H_2O_{(g)}$

Step 2) ? n=PV/RT

N=(150kPa x 300L) / (8.314LkPa/Kmol x 313.15K)

N=17.2…mol

Step 3) X/2mol= 17.2…mol/1mol

X=34.5…mol

Step 4) V=nRT/P

V=34.5…mol x 8.314LkPa/Kmol x 313.15K / 150kPa

V=600L; $\mathbf{V=6.0 \times 10^{2}L}$

3. A Down's Cell is used in the industrial production of sodium from the decomposition of molten sodium chloride. What is the temperature of 250 L of chlorine gas produced at 100.1 kPa if 100.0 g of sodium is also produced?

Step 1) **2** $NaCl_{(l)}$ → $2Na_{(s)}$ **+** $Cl_{2(g)}$
Step 2) n=m/M ? K

n=100g/22.99g/mol
n=4.3…mol

Step 3) 4.3…mol/2mol= x/1mol
X=2.1…mol

Step 4) T=PV/nR
T=100.1kPax250L / (2.1…mol x 8.314)
<u>T=1.38 x 10^3 K or 1.11 x 10^3 C</u>

4. A typical home is heated with natural gas and consumes 2.00 ML of natural gas during the month of December. What volume of oxygen at STP is required to burn 2.00 ML of methane measured at 0°C and 120 kPa?

Step 1) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$

Step 2) **n=PV/RT ?**

N=120kPa x 2.00x10^6/(8.314 x 273.15K)

N=105681…mol

Step 3) **105681…mol/1mol=x/2mol**

X=211362…mol

Step 4) **V=nV or V=nRT/P**

V=211362…mol x 22.4L/mol

V=4.73 x 10^6 L or 4.73 ML

5. Methane reacts with steam to produce hydrogen gas and carbon dioxide gas. What volume of hydrogen gas, measured at 25°C and 120 kPa, can be produced from 1.0 t of steam?

Step 1) $CH_{4(g)} + 2H_2O_{(g)} \rightarrow CO_{2(g)} + 4H_{2(g)}$

Step 2) **n=m/M**

n=1000000g/18.02g/mol

n=55493…mol

Step 3) **55493…mol/2mol = x/4mol**

X=11098…mol

Step 4) **V=nRT/P**

V=11098x8.314x298.15K/120kPa

V=2.3 ML or 2.3 x 10^{6}L

6. Hydrogen gas can be produced from the electrolytic decomposition of water. What volume of hydrogen gas is produced, along with 52 kL of oxygen gas, at 25°C and 120kPa?

Step 1) $2H_2O_{(g)} \rightarrow 2H_{2(g)} + O_{2(g)}$

Step 2) ? n=PV/RT

n=(120kPa x 52000L)/(8.314 x 298.15)

n=2517…mol

Step 3) X/2mol = 2517…mol/1mol

X=5034…mol

Step 4) V=nRT/P; V=5034…mol x 8.314 x 298.15K/120kPa

V=104000L; <u>V=1.0 x 10^5 L or 0.10 ML</u>

Worksheet 2.18: Review of Gases

Name: ___________

1. A volume of 20.0 L of oxygen is warmed from -30.0 C to 85.0 C. What is the new volume, if the pressure is kept constant?

   V_2=$V_1$$T_2$/$T_1$; V_2=

   V_2=29.5L

2. A mass of air occupies a volume of 5.7 L at a pressure of 0.52 atm. What is the new pressure if the same mass of air at the same temperature is transferred to a 2.0 L container?

   P_2=$P_1$$V_1$/$V_2$; P_2=

   P2=1.5 atm

3. Determine the total pressure of a gas mixture that contains CO, Ne and He if the partial pressures of the gases are P_{CO} = 1.53 atm, P_{Ne} = 0.82 atm, and P_{He} = 0.34 atm.

$P_t=P_1+P_2+P_3$; $P_t=$

P_t=2.69 atm (2 decimal places are significant because you are adding.)

4. What is the volume of a sample of oxygen gas that has a mass of 50.0 g and is under a pressure of 1.20 atm at 27.0 C?

V=nRT/P; V=

V=32.1L

5. What is the volume at STP of a sample of carbon dioxide gas that has a volume of 75.0 mL at 30.0 C and 680 mmHg?

$V_1=P_2V_2T_1/(T_2P_1)$; $V_1=$

V_1=0.0605L or 60.5 mL

6. A rigid container holds a gas at a pressure of 0.55 atm at a temperature of -100 C. What will the pressure be when the temperature is increased to 200 C?

$P_2=P_1T_2/T_1$; P_2

P_2=1.5 atm

7. Explain why real gases deviate from the gas laws.

Real gases deviate because they can be condensed into liquids, have particle size and attract each other, unlike ideal gases.