

## WORKSHOP ON STOICHIOMETRY

Q1. Calculate the mass of 2.0 mol of silicon.

Atomic weight of Si = 28.09

Mass of 2 mol of Si =  $2.0 \times 28.09 = 56.18 = 56$  g (2 significant figures)

Q2. Calculate the mass of 0.37 mol of barium chloride.

Formula weight of  $\text{BaCl}_2 = 137.3 + (2 \times 35.45) = 208.2$

Mass of 0.37 mol of  $\text{BaCl}_2 = 0.37 \times 208.2 = 77.034 = 77$  g (2 significant figures)

Q3. Calculate the amount (in mol) present in 2.8 g sulfur.

$n = m/M = 2.8/32.07 = 0.08731 = 0.087$  (2 significant figures)

Q4. Calculate the amount (in mol) present in 36.0 g of water.

Molecular weight of water is  $16.00 + (2 \times 1.008) = 18.016$

$n = m/M = 36.0/18.016 = 1.998 = 2.00$  (3 significant figures)

Q5. Calculate the mass of  $6.022 \times 10^{23}$  molecules of hydrogen.

Molecular weight of  $\text{H}_2 = 2 \times 1.008 = 2.016$

$n = 6.022 \times 10^{23} / N_A = 1.000$  mol

$m = n \times M = 1.000 \times 2.016 = 2.016$  g (4 significant figures)

Q6. Calculate the amount (in mol) present in  $2.0 \times 10^{20}$  molecules of carbon dioxide.

$n = 2.0 \times 10^{20} / N_A = 3.321 \times 10^{-4} = 3.3 \times 10^{-4}$  mol (2 significant figures)

Q7. Calculate the amount (in mol) present in 5.6 L of argon at STP.

1 mol of any gas at STP occupies 22.4 L

$\therefore$  5.6 L of Ar =  $5.6 / 22.4 = 0.25$  mol

Q8. Calculate the mass of 50.0 L of nitrogen gas at STP.

1 mol of any gas at STP occupies 22.4 L

$\therefore$  50.0 L of  $\text{N}_2 = 50.0 / 22.4 = 2.232$  mol

Molecular weight of  $\text{N}_2 = 2 \times 14.01 = 28.02$

$m = n \times M = 2.232 \times 28.02 = 62.545 = 62.5$  g (3 significant figures)

Q9. Calculate the atomic weight and the molecular weight of a natural sample of chlorine, which contains the isotopes:  $^{35}\text{Cl}$  (at. wt. 34.97, 75.77%) and  $^{37}\text{Cl}$  (at. wt. 36.97, 24.23%).

Atomic weight of Cl =  $34.97 \times 0.7577 + 36.97 \times 0.2423 = 35.45$  (4 significant figures)

Molecular weight of  $\text{Cl}_2 = 35.45 \times 2 = 70.90$

Q10. Determine the percentage by weight of bromide ion in potassium bromide (KBr).

Atomic weight of Br = 79.90      Atomic weight of K = 39.10

% weight of Br in KBr =  $79.9 / (39.10 + 79.90) = 0.6714 = 67.14\%$

W1-2

Q11. An iron ore has the composition of 70.0% Fe and 30.0% O by mass. What is the empirical formula of the ore?

$$\begin{aligned}\text{Fe} : \text{O} &= \frac{\% \text{ Fe}}{\text{at. wt Fe}} : \frac{\% \text{ O}}{\text{at. wt O}} \\ &= \frac{70.0}{55.85} : \frac{30.0}{16.00}\end{aligned}$$

$$= 1.250 : 1.875 = 1 : 1.5 = 2 : 3$$

Empirical formula is  $\text{Fe}_2\text{O}_3$

Q12. An organic compound containing only carbon, hydrogen and oxygen returns the % mass analysis: C 64.9 %; H 13.5 %. What is its empirical formula?

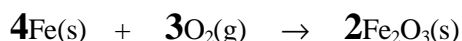
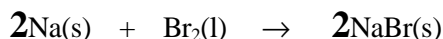
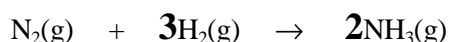
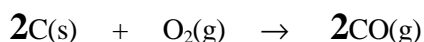
$$\% \text{O} = 100 - (64.9 + 13.5) = 21.6\%$$

$$\begin{aligned}\text{C} : \text{H} : \text{O} &= \frac{\% \text{ C}}{\text{at. wt C}} : \frac{\% \text{ H}}{\text{at. wt H}} : \frac{\% \text{ O}}{\text{at. wt O}} \\ &= \frac{64.9}{12.01} : \frac{13.5}{1.008} : \frac{21.6}{16.00}\end{aligned}$$

$$= 5.404 : 13.39 : 1.350 = 4.00 : 9.92 : 1.00 \approx 4 : 10 : 1$$

Empirical formula is  $\text{C}_4\text{H}_{10}\text{O}$

Q13. Balance each of the following molecular equations:



Q14. Complete the following table. (See page E1-2 if you need help.)

Formula	Name	Formula	Name
$\text{OH}^-$	<b>hydroxide ion</b>	$\text{CH}_3\text{CO}_2^-$	acetate ion
$\text{NO}_2^-$	nitrite ion	$\text{CN}^-$	<b>cyanide ion</b>
$\text{NO}_3^-$	nitrate ion	$\text{HS}^-$	<b>hydrosulfide ion</b>
$\text{C}_2\text{O}_4^{2-}$	<b>oxalate ion</b>	$\text{MnO}_4^-$	permanganate ion
$\text{ClO}_4^-$	perchlorate ion	$\text{HCO}_3^-$	hydrogencarbonate ion
$\text{CO}_3^{2-}$	carbonate ion	$\text{PO}_4^{3-}$	phosphate ion
$\text{S}_2\text{O}_3^{2-}$	<b>thiosulfate ion</b>	$\text{H}_2\text{PO}_4^-$	<b>dihydrogenphosphate ion</b>
$\text{SO}_4^{2-}$	sulfate ion	$\text{NH}_4^+$	ammonium ion
$\text{SO}_3^{2-}$	sulfite ion	$\text{Cr}_2\text{O}_7^{2-}$	<b>dichromate ion</b>

Q15. Indicate the charges on the ions and balance the following ionic equations:

$\text{KI(s)} \rightarrow \text{K}^+(\text{aq}) + \text{I}^-(\text{aq})$
$\text{Na}_2\text{CO}_3(\text{s}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$
$\text{NH}_4\text{Cl(s)} \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$
$\text{Ca(OH)}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$

Q16. Write the ionic equations for the reactions that occur when solid sodium carbonate and solid calcium chloride dissolve in water. Also write the ionic equation for the precipitation of calcium carbonate resulting from mixing the two solutions.

$\text{Na}_2\text{CO}_3(\text{s}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$
$\text{CaCl}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq})$
$\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CaCO}_3(\text{s})$

Q17. Calculate the mass of sodium carbonate ( $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ ) required to make 250 mL of a 0.100 M solution.

$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  has formula weight of  $(2 \times 22.99) + 12.01 + (3 \times 16.00) + (10 \times 18.016) = 286.15$   
 1000 mL of 0.100 M solution contains 0.100 mol  
 250 mL of 0.100 M solution contains  $(0.100 \times 0.250)$  mol of  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$   
 250 mL of 0.100 M solution contains  $(0.100 \times 0.250) \times 286.15$  g of  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$   
 $= 7.15$  g (3 significant figures)

Q18. What mass of barium sulfate will be precipitated when 125 mL of a 0.20 M solution of barium chloride is mixed with 200 mL of a 0.17 M solution of sodium sulfate. (Hint: work out which reagent is limiting.)

$\text{BaCl}_2 + \text{Na}_2\text{SO}_4 \rightarrow \text{BaSO}_4 + 2\text{NaCl}$   
 Amount of  $\text{BaCl}_2 = 0.20 \times 0.125 = 0.025$  mol  
 Amount of  $\text{Na}_2\text{SO}_4 = 0.17 \times 0.200 = 0.034$  mol  
 Therefore  $\text{BaCl}_2$  is the limiting reagent  
 Formula weight of  $\text{BaSO}_4 = 137.3 + 32.07 + (4 \times 16.00) = 233.37$   
 Mass of  $\text{BaSO}_4$  precipitated  $= 233.37 \times 0.025 = 5.834 = 5.8$  (2 significant figures)

Q19. Pure formic acid ( $\text{HCOOH}$ ), is a liquid monoprotic acid decomposed by heat to carbon dioxide and hydrogen, according to the following equation:



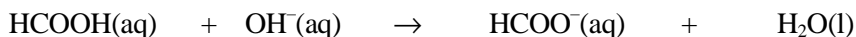
(i) The density of formic acid is  $1.220 \text{ g mL}^{-1}$ . How many moles of  $\text{HCOOH}$  are in 1 L of pure formic acid?

Molecular weight of  $\text{HCOOH} = 12.01 + (2 \times 1.008) + (2 \times 16.00) = 46.026$   
 1 mL of  $\text{HCOOH}$  has mass 1.220 g  
 1000 mL of  $\text{HCOOH}$  has mass 1220 g  
 1000 mL of  $\text{HCOOH}$  contains  $1220 / 46.026 = 26.51$  mol (4 significant figures)

(ii) What mass of pure formic acid should be diluted to 1.00 L to form a 2.00 M solution?

Molecular weight of  $\text{HCOOH} = 12.01 + (2 \times 1.008) + (2 \times 16.00) = 46.026$   
 2.00 mol of  $\text{HCOOH}$  has mass  $2.00 \times 46.026 = 92.052 = 92.1 \text{ g}$  (3 significant figures)

(iii) What volume of 0.250 M sodium hydroxide solution would react with 30.0 mL of this dilute solution of formic acid, according to the following equation?



30.0 mL of 2.00 M  $\text{HCOOH}$  solution contains  $2.00 \times 0.0300 = 0.0600 \text{ mol}$  of  $\text{HCOOH}$   
 Volume = amount / concentration =  $0.0600 / 0.250 = 0.240 \text{ L} = 240 \text{ mL}$  (3 significant figures)

(iv) What is the maximum volume of carbon dioxide at STP that could be obtained by heating 1.0 mol of formic acid?

From equation stoichiometry, 1 mol of  $\text{HCOOH}$  produces 1 mol of  $\text{CO}_2$ .  
 1 mol of any gas at STP has volume 22.4 L.

(v) How many molecules of carbon dioxide would it contain?

1 mol of any substance contains  $N_A$  molecules =  $6.022 \times 10^{23}$  molecules.

Q20. Consider the reaction  $4\text{Al}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{Al}_2\text{O}_3(\text{s})$

Identify the limiting reagent in each of the following reaction mixtures. What mass of  $\text{Al}_2\text{O}_3(\text{s})$  will be produced in each case?

1.0 mol Al and 1.0 mol $\text{O}_2$ Al is limiting 4 mol of Al reacts with 3 mol of $\text{O}_2$ to give 2 mol of $\text{Al}_2\text{O}_3$ Therefore 1 mol Al reacts with $3/4$ mol of $\text{O}_2$ to give $2/4$ mol of $\text{Al}_2\text{O}_3$ Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98) + (3 \times 16.00) = 101.96$ $2/4$ mol of $\text{Al}_2\text{O}_3$ has mass $101.96 \times 2 / 4 = 50.98 = 51 \text{ g}$ (2 significant figures)
0.75 mol Al and 0.5 mol $\text{O}_2$ $\text{O}_2$ is limiting 4 mol of Al reacts with 3 mol of $\text{O}_2$ to give 2 mol of $\text{Al}_2\text{O}_3$ Therefore 0.5 mol of $\text{O}_2$ reacts with $4 \times 0.5 / 3$ mol of Al to give $2 \times 0.5 / 3$ mol of $\text{Al}_2\text{O}_3$ Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98) + (3 \times 16.00) = 101.96$ $2 \times 0.5 / 3$ mol of $\text{Al}_2\text{O}_3$ has mass $101.96 \times 2 \times 0.5 / 3 = 33.99 = 34 \text{ g}$ (2 significant figures)
75.89 g Al and 112.25 g $\text{O}_2$ Amount of Al = $75.89 / 26.98 = 2.8128 \text{ mol}$ Amount of $\text{O}_2 = 112.25 / 32.00 = 3.5078 \text{ mol}$ Al is limiting 4 mol of Al reacts with 3 mol of $\text{O}_2$ to give 2 mol of $\text{Al}_2\text{O}_3$ Therefore 2.813 mol of Al reacts with $3 \times 2.813 / 4$ mol of $\text{O}_2$ to give $2 \times 2.813 / 4$ mol of $\text{Al}_2\text{O}_3$ Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98) + (3 \times 16.00) = 101.96$ $2 \times 2.813 / 4$ mol of $\text{Al}_2\text{O}_3$ has mass $101.96 \times 2 \times 2.813 / 4 = 143.4 \text{ g}$ (4 significant figures)
51.28 g Al and 48.22 g $\text{O}_2$ Amount of Al = $51.28 / 26.98 = 1.9007 \text{ mol}$ Amount of $\text{O}_2 = 48.22 / 32.00 = 1.5069 \text{ mol}$ Al is limiting 4 mol of Al reacts with 3 mol of $\text{O}_2$ to give 2 mol of $\text{Al}_2\text{O}_3$ Therefore 1.9007 mol of Al reacts with $3 \times 1.9007 / 4$ mol of $\text{O}_2$ to give $2 \times 1.9007 / 4$ mol of $\text{Al}_2\text{O}_3$ Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98) + (3 \times 16.00) = 101.96$ $2 \times 1.9007 / 4$ mol of $\text{Al}_2\text{O}_3$ has mass $101.96 \times 2 \times 1.9007 / 4 = 96.90 \text{ g}$ (4 significant figures)