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 $BaCl_2 = 137.3 + (2 \times 35.45) = 208.2$
Mass of 0.37 mol of $BaCl_2 = 0.37 \times 208.2 = 77.034 = 77$ 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 6.022×10^{23} molecules of hydrogen.

Molecular weight of $H_2 = 2 \times 1.008 = 2.016$
$n = 6.022 \times 10^{23} / N_A = 1.000$ mol
$m = n \times M = 1.000 \times 2.016 = 2.016$ g (4 significant figures)

Q6. Calculate the amount (in mol) present in 2.0×10^{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 N_2 = 50.0 / 22.4 = 2.232 mol
Molecular weight of $N_2 = 2 \times 14.01 = 28.02$
$m = n \times M = 2.232 \times 28.02 = 62.545 = 62.5$ g (3 significant figures)

Q9. Calculate the atomic weight and the molecular weight of a natural sample of chlorine, which contains the isotopes: ^{35}Cl (at. wt. 34.97, 75.77%) and ^{37}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 $Cl_2 = 35.45 \times 2 = 70.90$

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%

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?

$Fe : O = \frac{\% Fe}{at.\ wt\ Fe} : \frac{\% O}{at.\ wt\ O}$
$= \frac{70.0}{55.85} : \frac{30.0}{16.00}$
$= 1.250 : 1.875 \quad = 1 : 1.5 \quad = 2 : 3$
Empirical formula is Fe_2O_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?

$\%O = 100 - (64.9 + 13.5) = 21.6\%$
$C : H : O = \frac{\% C}{at.\ wt\ C} : \frac{\% H}{at.\ wt\ H} : \frac{\% O}{at.\ wt\ O}$
$= \frac{64.9}{12.01} : \frac{13.5}{1.008} : \frac{21.6}{16.00}$
$= 5.404 : 13.39 : 1.350 = 4.00 : 9.92 : 1.00 \approx 4 : 10 : 1$
Empirical formula is $C_4H_{10}O$

Q13. Balance each of the following molecular equations:

2C(s) + O_2(g) → **2**CO(g)
N_2(g) + **3**H_2(g) → **2**NH_3(g)
2Na(s) + Br_2(l) → **2**NaBr(s)
4Fe(s) + **3**O_2(g) → **2**Fe_2O_3(s)

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

Formula	Name	Formula	Name
OH^-	**hydroxide ion**	$\mathbf{CH_3CO_2^-}$	acetate ion
$\mathbf{NO_2^-}$	nitrite ion	CN^-	**cyanide ion**
$\mathbf{NO_3^-}$	nitrate ion	HS^-	**hydrogensulfide ion**
$C_2O_4^{2-}$	**oxalate ion**	$\mathbf{MnO_4^-}$	permanganate ion
$\mathbf{ClO_4^-}$	perchlorate ion	$\mathbf{HCO_3^-}$	hydrogencarbonate ion
$\mathbf{CO_3^{2-}}$	carbonate ion	$\mathbf{PO_4^{3-}}$	phosphate ion
$S_2O_3^{2-}$	**thiosulfate ion**	$H_2PO_4^-$	**dihydrogenphosphate ion**
$\mathbf{SO_4^{2-}}$	sulfate ion	$\mathbf{NH_4^+}$	ammonium ion
$\mathbf{SO_3^{2-}}$	sulfite ion	$Cr_2O_7^{2-}$	**dichromate ion**

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

$KI(s) \rightarrow K^{+}(aq) + I^{-}(aq)$
$Na_2CO_3(s) \rightarrow \mathbf{2}Na^{+}(aq) + CO_3^{2-}(aq)$
$NH_4Cl(s) \rightarrow NH_4^{+}(aq) + Cl^{-}(aq)$
$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + \mathbf{2}OH^{-}(aq)$

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.

$Na_2CO_3(s) \rightarrow 2Na^{+}(aq) + CO_3^{2-}(aq)$
$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^{-}(aq)$
$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

Q17. Calculate the mass of sodium carbonate ($Na_2CO_3{\cdot}10H_2O$) required to make 250 mL of a 0.100 M solution.

$Na_2CO_3{\cdot}10H_2O$ 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 (0.100×0.250) mol of $Na_2CO_3{\cdot}10H_2O$
250 mL of 0.100 M solution contains $(0.100 \times 0.250) \times 286.15$ g of $Na_2CO_3{\cdot}10H_2O$
= 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.)

$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$
Amount of = $BaCl_2 = 0.20 \times 0.125 = 0.025$ mol
Amount of = $Na_2SO_4 = 0.17 \times 0.200 = 0.034$ mol
Therefore $BaCl_2$ is the limiting reagent
Formula weight of $BaSO_4 = 137.3 + 32.07 + (4 \times 16.00) = 233.37$
Mass of $BaSO_4$ precipitated $= 233.37 \times 0.025 = 5.834 = 5.8$ (2 significant figures)

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

$$HCOOH(l) \rightarrow H_2(g) + CO_2(g)$$

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

Molecular weight of HCOOH $= 12.01 + (2 \times 1.008) + (2 \times 16.00) = 46.026$
1 mL of HCOOH has mass 1.220 g
1000 mL of HCOOH has mass 1220 g
1000 mL of 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 HCOOH = 12.01 + (2×1.008) + (2×16.00) = 46.026 2.00 mol of HCOOH has mass 2.00×46.026 = 52.052 = 92.1 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?

$$HCOOH(aq) + OH^-(aq) \rightarrow HCOO^-(aq) + H_2O(l)$$

30.0 mL of 2.00 M HCOOH solution contains 2.00×0.0300 = 0.0600 mol of HCOOH Volume = amount / concentration = 0.0600 / 0.250 = 0.240 L = 240 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 HCOOH produces 1 mol of 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 = 6.022×10^{23} molecules.

Q20. Consider the reaction $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

Identify the limiting reagent in each of the following reaction mixtures. What mass of $Al_2O_3(s)$ will be produced in each case?

1.0 mol Al and 1.0 mol O_2 Al is limiting 4 mol of Al reacts with 3 mol of O_2 to give 2 mol of Al_2O_3 Therefore 1 mol Al of reacts with 3/4 mol of O_2 to give 2/4 mol of Al_2O_3 Formula weight of Al_2O_3 = $(2 \times 26.98) + (3 \times 16.00)$ = 101.96 2/4 mol of Al_2O_3 has mass $101.96 \times 2 / 4$ = 50.98 = 51 g (2 significant figures)
0.75 mol Al and 0.5 mol O_2 O_2 is limiting 4 mol of Al reacts with 3 mol of O_2 to give 2 mol of Al_2O_3 Therefore 0.5 mol of O_2 reacts with $4 \times 0.5 / 3$ mol of Al to give $2 \times 0.5 / 3$ mol of Al_2O_3 Formula weight of Al_2O_3 = $(2 \times 26.98) + (3 \times 16.00)$ = 101.96 $2 \times 0.5 / 3$ mol of Al_2O_3 has mass $101.96 \times 2 \times 0.5 / 3$ = 33.99 = 34 g (2 significant figures)
75.89 g Al and 112.25 g O_2 Amount of Al = 75.89 / 26.98 = 2.8128 mol Amount of O_2 = 112.25 / 32.00 = 3.5078 mol Al is limiting 4 mol of Al reacts with 3 mol of O_2 to give 2 mol of Al_2O_3 Therefore 2.813 mol of Al reacts with $3\times2.813/4$ mol of O_2 to give $2\times2.813/4$ mol of Al_2O_3 Formula weight of Al_2O_3 = $(2 \times 26.98) + (3 \times 16.00)$ = 101.96 $2 \times 2.813 / 4$ mol of Al_2O_3 has mass $101.96 \times 2 \times 2.813 / 4$ = 143.4 g (4 significant figures)
51.28 g Al and 48.22 g O_2 Amount of Al = 51.28 / 26.98 = 1.9007 mol Amount of O_2 = 48.22 / 32.00 = 1.5069 mol Al is limiting 4 mol of Al reacts with 3 mol of O_2 to give 2 mol of Al_2O_3 Therefore 1.9007 mol of Al reacts with $3\times1.9007/4$ mol of O_2 to give $2\times1.9007/4$ mol of Al_2O_3 Formula weight of Al_2O_3 = $(2 \times 26.98) + (3 \times 16.00)$ = 101.96 $2 \times 1.9007 / 4$ mol of Al_2O_3 has mass $101.96 \times 2 \times 1.9007 / 4$ = 96.90 g (4 significant figures)