

W1 WORKSHOP ON STOICHIOMETRY
worked answers to workshop

Q1. Calculate the mass of 2.0 mol of silicon.

Atomic mass of Si = 28.09

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

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

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

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

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

$$n = \frac{m}{M} = \frac{2.8}{32.07} = 0.08731 = 0.087 \text{ (2 significant figures)}$$

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

Molecular weight of water is $16.00 \text{ (O)} + (2 \times 1.008 \text{ (H)}) = 18.016$

$$n = \frac{m}{M} = \frac{36.0}{18.016} = 1.998 = 2.00 \text{ (3 significant figures)}$$

Q5. Calculate the mass of 6.022×10^{23} molecules of hydrogen.

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

$$n = \frac{\text{number of atoms}}{\text{Avogadro's number}} = \frac{6.022 \times 10^{23}}{6.022 \times 10^{23}} = 1.000 = 1.000 \text{ mol}$$

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

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

$$n = \frac{\text{number of atoms}}{\text{Avogadro's number}} = \frac{2.0 \times 10^{20}}{6.022 \times 10^{23}} = 3.321 \times 10^{-4} \text{ mol}$$
$$= 3.3 \times 10^{-4} \text{ mol (2 significant figures)}$$

continues on the next page

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

$$\therefore 5.6 \text{ L of Ar} = \frac{\text{volume of gas (in L)}}{22.4 \text{ L}} = \frac{5.6}{22.4} = 0.25 \text{ mol}$$

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

1 mol of any gas at STP occupies 22.4 L

$$\therefore 50.0 \text{ L of N}_2 = \frac{\text{volume of gas (in L)}}{22.4 \text{ L}} = \frac{50.0}{22.4} = 2.232 \text{ mol}$$

Molecular weight of N₂ = 2 × 14.01 = 28.02

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

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

The relative atomic mass of chlorine is the weighted average of the masses of its isotopes:

$$\left(34.97 \times \frac{75.77}{100} \right) + \left(36.97 \times \frac{24.23}{100} \right) = 35.45 \text{ (4 significant figures)}$$

Molecular weight of Cl₂ = 35.45 × 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

$$\% \text{ weight of Br in KBr} = \frac{79.90}{(39.10 + 79.90)} = 67.14\%$$

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
amount in 100 g	70.0	30.0
ratio (divide by atomic mass)	$\frac{70.0}{55.85} = 1.250$	$\frac{30.0}{16.00} = 1.875$
divide by smallest	$\frac{1.250}{1.250} = 1.000 \sim 1$	$\frac{1.875}{1.250} = 1.500 \sim 1.5$

The smallest integer ratio is 2: 3 so the 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?

As the compound contains only C, H and O, their percentages by mass must add up to 100%. Hence, the percentage of O is $100 - (64.9 + 13.5) = 21.6 \%$

	C	H	O
amount in 100 g	64.9	13.5	21.6
ratio (divide by atomic mass)	$\frac{64.9}{12.01} = 5.404$	$\frac{13.5}{1.008} = 13.39$	$\frac{21.6}{16.00} = 1.350$
divide by smallest	$\frac{5.404}{1.350} = 4.00 \sim 4$	$\frac{13.39}{1.350} = 9.92 \sim 10$	$\frac{1.350}{1.350} = 1.00 \sim 1$

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

continues on the next page

Q13. Balance each of the following molecular equations:

$2\text{C(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CO(g)}$
$\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightarrow 2\text{NH}_3\text{(g)}$
$2\text{Na(s)} + \text{Br}_2\text{(l)} \rightarrow 2\text{NaBr(s)}$
$4\text{Fe(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)}$

Q14. Complete the following table. (See page E2-1 if you need help.)

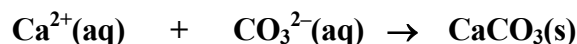
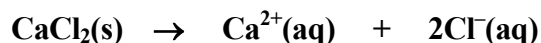
Formula	Name	Formula	Name
OH^-	hydroxide ion	CH_3CO_2^-	acetate ion
NO_2^-	nitrite ion	CN^-	cyanide ion
NO_3^-	nitrate ion	HS^-	hydrosulfide ion
$\text{C}_2\text{O}_4^{2-}$	oxalate ion	MnO_4^-	permanganate ion
ClO_4^-	perchlorate ion	HCO_3^-	hydrogencarbonate ion
CO_3^{2-}	carbonate ion	PO_4^{3-}	phosphate ion
$\text{S}_2\text{O}_3^{2-}$	thiosulfate ion	H_2PO_4^-	dihydrogenphosphate ion
SO_4^{2-}	sulfate ion	NH_4^+	ammonium ion
SO_3^{2-}	sulfite ion	$\text{Cr}_2\text{O}_7^{2-}$	dichromate ion

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

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

continues on the next page

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.



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:

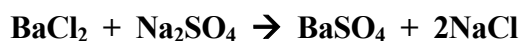
$$(2 \times 22.99 (\text{Na})) + 12.01 (\text{C}) + (3 \times 16.00 (\text{O})) + 10 \times (16.00 (\text{O}) + 2 \times 1.008 (\text{H})) = 286.15$$

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 $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

**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.)



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

As *one* mole of BaCl_2 is required for every *one* mole of Na_2SO_4 , BaCl_2 is the limiting reagent

Formula weight of $\text{BaSO}_4 = 137.3 (\text{Ba}) + 32.07 (\text{S}) + (4 \times 16.00 (\text{O})) = 233.37$

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:



- (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 = $12.01 \text{ (C)} + (2 \times 1.008 \text{ (H)}) + (2 \times 16.00 \text{ (O)}) = 46.026$

1 mL of HCOOH has mass 1.220 g

1000 mL of HCOOH has mass 1220 g

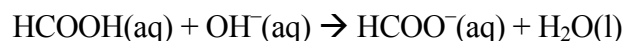
1000 mL of HCOOH contains $1220 / 46.026 = 26.51 \text{ mol}$ (4 significant figures)

- (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 = $12.01 \text{ (C)} + (2 \times 1.008 \text{ (H)}) + (2 \times 16.00 \text{ (O)}) = 46.026$

2.00 mol of 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 HCOOH solution contains $2.00 \times 0.0300 = 0.0600 \text{ mol}$ of HCOOH

Volume = $\frac{\text{number of moles (in mol)}}{\text{concentration (in M)}} = \frac{0.0600}{0.250} = 0.240 \text{ L} = 240 \text{ mL}$ (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 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 $4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$

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 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 of Al reacts with $\frac{3}{4}$ mol of O_2 to give $\frac{2}{4}$ mol of Al_2O_3

Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98 \text{ (Al)}) + (3 \times 16.00 \text{ (O)}) = 101.96$

$\frac{2}{4}$ mol of Al_2O_3 has mass $101.96 \times \frac{2}{4} = 50.98 = 51 \text{ g}$ (2 significant figures)

0.75 mol Al and 0.50 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 $4 \times \frac{0.5}{3}$ mol of Al react with 0.5 mol of O_2 reacts with to give $2 \times \frac{0.5}{3}$ mol of Al_2O_3

Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98 \text{ (Al)}) + (3 \times 16.00 \text{ (O)}) = 101.96$

$2 \times \frac{0.5}{3}$ mol of Al_2O_3 has mass $101.96 \times 2 \times \frac{0.5}{3} = 33.99 = 34 \text{ g}$ (2 significant figures)

75.89 g Al and 112.25 g O_2

Amount of Al = $\frac{75.89}{26.98} = 2.8128 \text{ mol}$ Amount of $\text{O}_2 = \frac{112.25}{(2 \times 16.00)} = 3.5078 \text{ mol}$

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 $3 \times \frac{2.813}{4}$ mol of O_2 to give $2 \times \frac{2.813}{4}$ mol of Al_2O_3

Formula weight of $\text{Al}_2\text{O}_3 = (2 \times 26.98 \text{ (Al)}) + (3 \times 16.00 \text{ (O)}) = 101.96$

$2 \times \frac{2.813}{4}$ mol of Al_2O_3 has mass $101.96 \times 2 \times \frac{2.813}{4} = 143.4 \text{ g}$ (4 significant figures)

continues on the next page

51.28 g Al and 48.22 g O₂

$$\text{Amount of Al} = \frac{51.28}{26.98} = 1.9007 \text{ mol} \quad \text{Amount of O}_2 = \frac{48.22}{(2 \times 16.00)} = 1.5069 \text{ mol}$$

Al is limiting

4 mol of Al reacts with 3 mol of O₂ to give 2 mol of Al₂O₃

Therefore 1.9007 mol of Al reacts with $3 \times \frac{1.9007}{4}$ mol of O₂ to give $2 \times \frac{1.9007}{4}$ mol of Al₂O₃

Formula weight of Al₂O₃ = (2 × 26.98 (Al)) + (3 × 16.00 (O)) = 101.96

$$2 \times \frac{1.9007}{4} \text{ mol of Al}_2\text{O}_3 \text{ has mass } 101.96 \times 2 \times \frac{1.9007}{4} = 96.90 \text{ g (4 significant figures)}$$