

1. One mole of silver has a mass of 107.9 g and consists of 6.022×10^{23} atoms. The mass of 12×10^{23} atoms is therefore:

$$\text{mass} = \left(\frac{12 \times 10^{23}}{6.02 \times 10^{23}} \right) \text{ mol} \times 107.9 \text{ g mol}^{-1} = 220 \text{ g}$$

As the number of atoms is only known to 2 significant figures, this mass should be rounded to 220 g.

1 mole of He has a mass of 4.003 g so 6 moles has a mass of $6 \times 4.003 \text{ g} = 24.018 \text{ g}$. The number of moles is given to three significant figures (6.00 has two trailing zeros indicating that it has been measured this accurately). The mass should therefore be rounded to 24.0 g.

The masses are therefore in the order:

$$\text{helium (24.0 g)} < \text{copper (100 g)} < \text{silver (220 g)}$$

2. The molar mass of C_2H_4 is $((2 \times 12.01 \text{ (C)}) + (4 \times 1.008 \text{ (H)})) \text{ g mol}^{-1} = 28.052 \text{ g mol}^{-1}$

The number of moles in 112 g of C_2H_4 is therefore:

$$\text{number of moles of } \text{C}_2\text{H}_4 = \frac{\text{mass}}{\text{molar mass}} = \frac{112 \text{ g}}{28.052 \text{ g mol}^{-1}} = 3.99 \text{ mol}$$

The mass of 112 g is known to 3 significant figures and so the answer is also given to this level of accuracy.

Each molecule of C_2H_4 is made up of 2 atoms of C and 4 atoms of H. Each mole of C_2H_4 is made up of 2 moles of C and 4 moles of H:

$$\text{number of moles of C} = 2 \times 3.99 \text{ mol} = 7.98 \text{ mol}$$

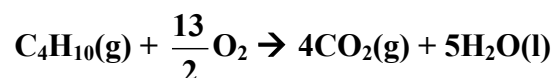
Again, the figure has been rounded to reflect the three significant figures given for the mass of ethylene.

3. The molar mass of C_4H_{10} is $((4 \times 12.01 \text{ (C)}) + (10 \times 1.008 \text{ (H)})) \text{ g mol}^{-1} = 58.12 \text{ g mol}^{-1}$

The number of moles in 10.0 g of C_4H_{10} is therefore:

$$\text{number of moles of } \text{C}_4\text{H}_{10} = \frac{\text{mass}}{\text{molar mass}} = \frac{10.0 \text{ g}}{58.12 \text{ g mol}^{-1}} = 0.172 \text{ mol}$$

The equation for the combustion is:



Every mole of C_4H_{10} produces (i) 4 moles of carbon dioxide and (ii) 5 moles of water and consumes (iii) $\frac{13}{2}$ moles of oxygen.

- (i) The number of moles of CO_2 produced is therefore $4 \times 0.172 = 0.688$ mol. Each mole of CO_2 has a mass of $(12.01 \text{ (C)} + 2 \times 16.00 \text{ (O)}) \text{ g mol}^{-1} = 44.01 \text{ g mol}^{-1}$. The mass of 0.688 mol of CO_2 is:

$$\text{mass of } CO_2 = \text{number of moles} \times \text{molar mass} = 0.688 \text{ mol} \times 44.01 \text{ g mol}^{-1} = 30.3 \text{ g.}$$

- (ii) The number of moles of H_2O produced is $5 \times 0.172 = 0.860$ mol. Each mole of H_2O has a mass of $(2 \times 1.008 \text{ (H)} + 16.00 \text{ (O)}) \text{ g mol}^{-1} = 18.016 \text{ g mol}^{-1}$. The mass of 0.860 mol of H_2O is:

$$\text{mass of } H_2O = \text{number of moles} \times \text{molar mass} = 0.860 \text{ mol} \times 18.016 \text{ g mol}^{-1} = 15.5 \text{ g.}$$

- (iii) The number of moles of O_2 produced is $\frac{13}{2} \times 0.172 = 1.118$ mol. Each mole of O_2 has a mass of $(2 \times 16.00) \text{ g mol}^{-1} = 32.00 \text{ g mol}^{-1}$. The mass of 1.118 mol of O_2 is:

$$\text{mass of } O_2 = \text{number of moles} \times \text{molar mass} = 1.118 \text{ mol} \times 32.00 \text{ g mol}^{-1} = 35.8 \text{ g.}$$

4. Sodium carbonate is Na_2CO_3 and has a formula mass of

$$\text{formula mass} = (2 \times 22.99 \text{ (Na)} + 12.01 \text{ (C)} + 3 \times 16.00 \text{ (O)}) \text{ g mol}^{-1} = 105.99 \text{ g mol}^{-1}$$

The number of moles in 53.0 g of Na_2CO_3 is therefore:

$$\text{number of moles of } Na_2CO_3 = \frac{\text{mass}}{\text{molar mass}} = \frac{53.0 \text{ g}}{105.99 \text{ g mol}^{-1}} = 0.500 \text{ mol}$$

The reaction is:



Two moles of $NaOH$ are required for every mole of Na_2CO_3 that is prepared. 0.500 moles of Na_2CO_3 therefore requires 1.00 mol of $NaOH$.

Each mole of $NaOH$ has a mass of $22.99 \text{ (Na)} + 16.00 \text{ (O)} + 1.008 \text{ (H)} = 39.998 \text{ g mol}^{-1}$. The mass of 1.00 mol of $NaOH$ is:

$$\begin{aligned} \text{mass of } NaOH &= \text{number of moles} \times \text{molar mass} \\ &= (39.998 \text{ mol}) \times (1.00 \text{ g mol}^{-1}) = 40.0 \text{ g.} \end{aligned}$$

Note that the mass of sodium carbonate is given in the question as 53.0 g. It is therefore known to 3 significant figures and the accuracy given in the answer reflects this.

5. Metals form the majority of the elements in the Periodic Table and occur on the left side of the Table. Non-metals are placed on the right side of the Table. There are a few metalloids or semi-metals on the border between metals and non-metals. The metalloids

are boron (B); silicon (Si); germanium (Ge); arsenic (As); antimony (Sb) and tellurium (Te).

6. Metals are solids at room temperature (with mercury the sole exception) - non-metals include solids, one liquid (bromine) and gasses.

Physical properties:

- Metals conduct electricity - non-metals do not (the allotrope of carbon, graphite, is an exception but is not a *metallic conductor* as its conductivity actually *increases* with temperature).
- Metals are shiny, malleable and ductile - non-metals are not normally associated with these properties.
- Metals usually have a higher density than non-metals.

Chemical properties:

- Metals are cationic and non-metals anionic in salts.S.
- Some metals react with acid to give hydrogen gas and the metal cation - nonmetals do not react in this way.
- Metal oxides are basic in nature - non-metal oxides are acidic.

7.

	N	Cl	H
amount in 100 g	26.2	66.4	7.5
ratio (divide by atomic mass)	$\frac{26.2}{14.01} = 1.87$	$\frac{66.4}{35.45} = 1.87$	$\frac{7.5}{1.08} = 7.44$
divide by smallest	$\frac{1.87}{1.87} = 1.00 \sim 1$	$\frac{1.87}{1.87} = 1.00 \sim 1$	$\frac{7.44}{1.87} = 3.98 \sim 4$

The empirical formula is NClH₄ – probably ammonium chloride [NH₄]⁺[Cl⁻]

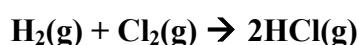
8. The molar mass of H₂ is 2 × 1.008 = 2.016 g mol⁻¹. The number of moles in 4.00 g is:

$$\text{number of moles} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1}\text{)}} = \frac{4.00 \text{ g}}{2.016 \text{ g mol}^{-1}} = 1.98 \text{ mol}$$

The molar mass of Cl₂ is 2 × 35.45 = 70.90 g mol⁻¹. The number of moles in 10.00 g is:

$$\text{number of moles} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1}\text{)}} = \frac{10.0 \text{ g}}{70.90 \text{ g mol}^{-1}} = 0.141 \text{ mol}$$

The reaction is:



One mole of H₂ reacts with *one* mole of Cl₂ to give *two* moles of HCl. There is more H₂ present than can react with the amount of Cl₂ – H₂ is in excess and at the end of the reaction (1.98 – 0.141) mol = 1.84 mol of H₂ will be left over.

The amount of HCl that can be formed is controlled or *limited* by the amount of Cl₂ available. Two moles of HCl is produced for every mole of Cl₂. As there is only 0.141 mol of Cl₂ available, the amount of HCl that can be formed is $2 \times 0.141 = 0.282$ mol. The molar mass of HCl is 1.008 (H) + 35.45 (Cl) = 36.458 g mol⁻¹.

The mass of HCl is therefore:

$$\begin{aligned}\text{mass} &= \text{number of moles (in mol)} \times \text{molar mass (g mol}^{-1}\text{)} \\ &= 0.282 \text{ mol} \times 36.458 \text{ g mol}^{-1} = 10.3 \text{ g}\end{aligned}$$

9. The number of moles of sodium required to make 250 mL of a 0.100 M solution is:

$$\begin{aligned}\text{number of moles} &= \text{volume (in L)} \times \text{concentration (in mol L}^{-1}\text{)} \\ &= \frac{250}{1000} \text{ L} \times 0.100 \text{ mol L}^{-1} = 0.0250 \text{ mol}\end{aligned}$$

The formula of sodium carbonate is Na₂CO₃ so its molar mass is:

$$\text{molar mass} = (2 \times 22.99 \text{ (Na)}) + 12.01 \text{ (C)} + 3 \times 16.00 \text{ (O)} \text{ g mol}^{-1} = 105.99 \text{ g mol}^{-1}$$

The mass of sodium carbonate required is therefore:

$$\begin{aligned}\text{mass} &= \text{number of moles (in mol)} \times \text{molar mass (g mol}^{-1}\text{)} \\ &= 0.0250 \text{ mol} \times 105.99 \text{ g mol}^{-1} = 2.65 \text{ g}\end{aligned}$$

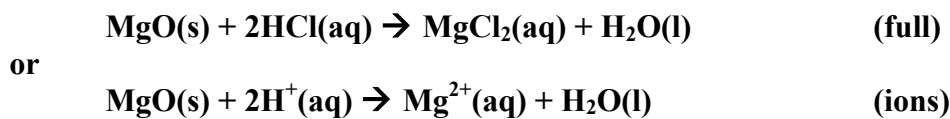
10. The formula of magnesium oxide is MgO so its formula mass is 24.31 (Mg) + 16.00 (O) = 40.31 g mol⁻¹. The number of moles in 2.00 g is:

$$\text{number of moles} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1}\text{)}} = \frac{2.00 \text{ g}}{40.31 \text{ g mol}^{-1}} = 0.0496 \text{ mol}$$

The number of moles of HCl in 10.0 mL of a 2.00 M solution is:

$$\begin{aligned}\text{number of moles} &= \text{volume (in L)} \times \text{concentration (in mol L}^{-1}\text{)} \\ &= \frac{10}{1000} \text{ L} \times 2.00 \text{ mol L}^{-1} = 0.0200 \text{ mol}\end{aligned}$$

The reaction is:



One mole of MgO reacts with *two* moles of acid. To react with all of the MgO available (0.0496 mol), (2×0.0496) mol = 0.0992 mol of acid would be required. Only 0.0200 mol of acid is available so MgO is *in excess* and some will be left at the end of the reaction.

As 0.0200 mol of HCl is available, only 0.0100 mol of MgO will react. The amount of MgO remaining at the end of the reaction is therefore $0.0496 - 0.0100 = 0.0396$ mol.

11. The formula of hydrazine is N_2H_4 so its molar mass is:

$$\text{molar mass} = (2 \times 14.01 \text{ (N)} + 4 \times 1.008 \text{ (H)}) \text{ g mol}^{-1} = 32.052 \text{ g mol}^{-1}$$

The number of moles of hydrazine in 1.00×10^2 g is therefore:

$$\text{number of moles (in mol)} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1}\text{)}} = \frac{1.00 \times 10^2 \text{ g}}{32.052 \text{ g mol}^{-1}} = 3.12 \text{ mol}$$

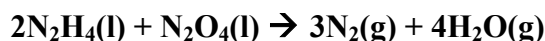
The formula of nitrogen tetroxide is N_2O_4 so its molar mass is:

$$\text{molar mass} = (2 \times 14.01 \text{ (N)} + 4 \times 16.00 \text{ (O)}) \text{ g mol}^{-1} = 92.02 \text{ g mol}^{-1}$$

The number of moles of nitrogen tetroxide in 2.00×10^2 g is therefore:

$$\text{number of moles (in mol)} = \frac{\text{mass}}{\text{molar mass}} = \frac{2.00 \times 10^2 \text{ g}}{92.02 \text{ g mol}^{-1}} = 2.17 \text{ mol}$$

The chemical equation for the reaction is:



Two moles of H_2H_4 react with *one* mole of N_2O_4 . The 2.17 mol of N_2O_4 present would require $2 \times 2.17 = 4.34$ mol of N_2H_4 to react fully. Less than this amount is available so N_2H_4 is the *limiting reagent* and controls the amount of product that can be made. N_2O_4 is *in excess* and some will be left over at the end of the reaction.

The amount of N_2 formed is limited by the amount of N_2H_4 available. The chemical equation shows that *three* moles of N_2 are made for every *two* moles of N_2H_4 . The number of moles of N_2 that will be made from 3.12 mol of N_2H_4 is therefore:

$$\text{number of moles of N}_2 = \frac{3}{2} \times 3.12 \text{ mol} = 4.68 \text{ mol}$$

The molar mass of N_2 is $2 \times 14.01 = 28.02 \text{ g mol}^{-1}$. The mass of 4.68 mol is:

$$\begin{aligned} \text{mass (in g)} &= \text{number of moles (in mol)} \times \text{molar mass (in g mol}^{-1}\text{)} \\ &= 4.68 \text{ mol} \times 28.02 \text{ g mol}^{-1} = 131 \text{ g} \end{aligned}$$

12. The formula of magnesium hydroxide $\text{Mg}(\text{OH})_2$ so its molar mass is:

$$\text{molar mass} = (24.31 \text{ (Mg)} + 2 \times (16.00 \text{ (O)} + 1.008 \text{ (H)})) \text{ g mol}^{-1} = 58.326 \text{ g mol}^{-1}$$

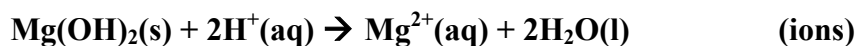
The number of moles of $\text{Mg}(\text{OH})_2$ in 0.10 g is therefore:

$$\text{number of moles (in mol)} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1}\text{)}} = \frac{0.10 \text{ g}}{58.326 \text{ g mol}^{-1}} = 0.0017 \text{ mol}$$

The chemical equation for the neutralization reaction is:



or



Two moles of acid are neutralized by every *one* mole of Mg(OH)_2 . As 0.0017 mol of Mg(OH)_2 are present in the tablet, $2 \times 0.0017 = 0.0034$ mol of acid will be neutralized. The volume of a 0.10 M solution of HCl containing this number of moles is:

$$\text{volume (in L)} = \frac{\text{number of moles (in mol)}}{\text{concentration (in mol L}^{-1}\text{)}} = \frac{0.0034 \text{ mol}}{0.10 \text{ mol L}^{-1}} = 0.034 \text{ L}$$

As 1 L = 1000 mL, 0.034 L = 34 mL.