Writing Chemical Equations

Write unbalanced chemical equations for the following chemical reactions. (Assume pure substances unless otherwise indicated. Include states of matter.)
Example: sodium metal + chlorine → sodium chloride
Answer: $Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$

1. water → hydrogen + oxygen
   $H_2O_{(l)} \rightarrow H_{2(g)} + O_{2(g)}$

2. nitrogen + hydrogen → ammonia
   $N_{2(g)} + H_{2(g)} \rightarrow NH_{3(g)}$

3. sulfuric acid + aqueous sodium hydroxide → water + aqueous sodium sulfate
   $H_2SO_{4(aq)} + NaOH_{(aq)} \rightarrow HOH_{(l)} + Na_2SO_{4(aq)}$

4. aluminum + aqueous copper(II) nitrate → copper + aqueous aluminum nitrate
   $Al_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow Cu_{(s)} + Al(NO_3)_{3(aq)}$

5. chlorine + aqueous potassium bromide → bromine + aqueous potassium chloride
   $Cl_{2(g)} + KBr_{(aq)} \rightarrow Br_{2(l)} + KCl_{(aq)}$

6. lead(II) nitrate$_{(aq)}$ + sodium iodide$_{(aq)}$ → lead(II) iodide$_{(s)}$ + sodium nitrate$_{(aq)}$
   $Pb(NO_3)_{2(aq)} + NaI_{(aq)} \rightarrow PbI_{2(s)} + NaNO_{3(aq)}$

7. aqueous sodium hydroxide + aqueous aluminum sulfate → solid aluminum hydroxide + aqueous sodium sulfate
   $NaOH_{(aq)} + Al_2(SO_4)_{3(aq)} \rightarrow Al(OH)_{3(s)} + Na_2SO_{4(aq)}$

8. phosphorus + oxygen → solid tetraphosphorus decaoxide
   $P_{4(s)} + O_{2(g)} \rightarrow P_4O_{10(s)}$

9. methanol + oxygen → carbon dioxide + water vapor
   $CH_3OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$

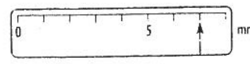
10. nitrogen dioxide gas + water → nitric acid + nitrogen monoxide gas
   $NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + NO_{(g)}$

Certainty and Precision

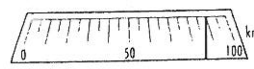
1. Communicate values with acceptable precision, for the following scale readings. Report the preci after each value; e.g., 12.5 cm (0.1 cm).

(a) 

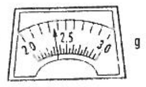
(a) 3.8 mm (0.1 mm)

(b) 

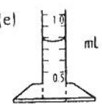
(b) 7.0 mm (0.1 mm)

(c) 

(c) 89 km/h (1 km/h)

(d) 

(d) 2.36 g (0.01 g)

(e) 

(e) 0.75 mL (0.01 mL)

2. For each of the measurements, give the certainty (report the number of significant digits).
   (a) 3.4 km — 2 sig digs
   (b) 51.85 g — 4 sig digs
   (c) 0.7 mL — 1 sig dig
   (d) 0.650 mol — 3 sig digs
   (e) 200.59 g/mol — 5 sig digs

3. Round each of the following calculated answers to three significant digits. Then change the prefix (if neces to report the answer according to the rule of a thousand.
   (a) 1266.65 g — 1.27 kg
   (b) 0.0175 L — 17.5 mL
   (c) 1879 mL — 1.88 L
   (d) 0.0874 g — 87.4 mg
   (e) 34.08 g/mol — 34.1 g/mol

4. For each of the following, show all work and report the answer in accepted units and certainty.
   (a) 46 mol × 44.01 g/mol — 2.0 kg
   (b) $454 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}}$ — 0.454 kg
   (c) 75.3 cm + 0.85 cm + 102 cm — 178 cm
   (d) 150.4 g + 32.06 g — 182.5 g
   (e) (39.10 + 12.01 + 14.01) g/mol × 0.225 mol — 14.7 g
   (f) 0.3785 m × 100 cm/m — 37.85
   (g) $4.79 \text{ g} \times \frac{1 \text{ mol}}{159.61 \text{ g}}$ — 30.0 m
   (h) 107.83 g − 98.52 g — 9.31 g
   (i) 29.6°C − 5.3°C — 24.3°C

5. The following are some experimentally determined molar masses for some common gases. Deter the accuracy of these values, i.e., calculate the percent difference between the respective experim and predicted values.
   (a) carbon dioxide, 45.2 g/mol and 44.01 g/mol — % difference = 2.7%
   (b) sulfur trioxide, 79.3 g/mol and 80.06 g/mol — % difference = 1%
   (c) dinitrogen pentoxide, 105.6 g/mol and 108.02 g/mol — % difference = 2.2%

Predicting Chemical Reactions

For each of the following questions, classify the reaction type (formation, simple decomposition, combustion, single replacement, double replacement, or other) and predict the balanced chemical equation. Provide a word equation as well.

1. $4\,Al_{(s)} + 3\,O_{2(g)} \rightarrow 2\,Al_2O_{3(s)}$
   formation or combustion
   aluminum + oxygen → aluminum oxide

2. $2\,Ag_2O_{(s)} \rightarrow 4\,Ag_{(s)} + O_{2(g)}$
   simple decomposition
   silver oxide → silver + oxygen

3. $Br_{2(l)} + 2\,KI_{(aq)} \rightarrow I_{2(s)} + 2\,KBr_{(aq)}$
   single replacement
   bromine + potassium iodide → iodine + potassium bromide

4. A strip of zinc metal is placed into a copper(II) nitrate solution.
   $Zn_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow Cu_{(s)} + Zn(NO_3)_{2(aq)}$
   single replacement
   zinc + copper(II) nitrate → copper + zinc nitrate

5. $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2\,NaCl_{(aq)}$
   double replacement
   barium chloride + sodium sulfate → barium sulfate + sodium chloride

6. Sulfuric acid is neutralized by aqueous sodium hydroxide.
   $H_2SO_{4(aq)} + 2\,NaOH_{(aq)} \rightarrow 2\,HOH_{(l)} + Na_2SO_{4(aq)}$
   double replacement
   sulfuric acid + sodium hydroxide → water + sodium sulfate

7. $Na_2S_{(aq)} + Cu(CH_3COO)_{2(aq)} \rightarrow CuS_{(s)} + 2\,NaCH_3COO_{(aq)}$
   double replacement
   sodium sulfide + copper(II) acetate → copper(II) sulfide + sodium acetate

8. $2\,CuS_{(s)} + 3\,O_{2(g)} \rightarrow 2\,CuO_{(s)} + 2\,SO_{2(g)}$
   combustion
   copper(II) sulfide + oxygen → copper(II) oxide + sulfur dioxide

9. Propane burns in air.
   $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(g)}$
   combustion
   propane + oxygen → carbon dioxide + water

10. $Na_2CO_{3(aq)} + 2\,HCl_{(aq)} \rightarrow 2\,NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$
   other
   sodium carbonate + hydrochloric acid → sodium chloride + carbon dioxide + water

Balancing Chemical Reaction Equations

Use the Dalton theory of the conservation of atoms to balance the following chemica equations.

1. $Ni_{(s)} + \mathbf{2}\,HCl_{(aq)} \rightarrow NiCl_{2(aq)} + H_{2(g)}$

2. $Ca(OH)_{2(s)} + \mathbf{2}\,HCl_{(aq)} \rightarrow CaCl_{2(aq)} + \mathbf{2}\,HOH_{(l)}$

3. $Cl_{2(g)} + \mathbf{2}\,NaBr_{(aq)} \rightarrow Br_{2(l)} + \mathbf{2}\,NaCl_{(aq)}$

4. $\mathbf{2}\,Cr_2O_{3(s)} \rightarrow \mathbf{4}\,Cr_{(s)} + \mathbf{3}\,O_{2(g)}$

5. $\mathbf{2}\,Fe_{(s)} + \mathbf{6}\,HCl_{(aq)} \rightarrow \mathbf{2}\,FeCl_{3(aq)} + \mathbf{3}\,H_{2(g)}$

6. $\mathbf{2}\,C_3H_{6(g)} + \mathbf{9}\,O_{2(g)} \rightarrow \mathbf{6}\,CO_{2(g)} + \mathbf{6}\,H_2O_{(g)}$

7. $P_{4(s)} + \mathbf{6}\,F_{2(g)} \rightarrow \mathbf{4}\,PF_{3(l)}$

8. $Ca(NO_3)_{2(aq)} + \mathbf{2}\,KOH_{(aq)} \rightarrow Ca(OH)_{2(s)} + \mathbf{2}\,KNO_{3(aq)}$

9. $\mathbf{2}\,KHCO_{3(s)} \rightarrow K_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$

10. $H_3PO_{4(aq)} + \mathbf{3}\,NaOH_{(aq)} \rightarrow Na_3PO_{4(aq)} + \mathbf{3}\,HOH_{(l)}$

11. $\mathbf{3}\,Ca(NO_3)_{2(aq)} + \mathbf{2}\,Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + \mathbf{6}\,NaNO_{3(aq)}$

12. $Cu_{(s)} + \mathbf{4}\,HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + \mathbf{2}\,NO_{2(g)} + \mathbf{2}\,H_2O_{(l)}$

Ionic Nomenclature

Write the international chemical formula or the English IUPAC name for each of the compounds given. (This exercise involves all classes of ionic compounds.)

	International Chemical Formula	IUPAC Name
1.	$SrCl_{2(s)}$	**strontium chloride**
2.	$RbBr_{(s)}$	**rubidium bromide**
3.	$Na_2O_{(s)}$	**sodium oxide**
4.	**$Al_2S_{3(s)}$**	aluminum sulfide
5.	**$ZnCl_{2(s)}$**	zinc chloride
6.	**$MgI_{2(s)}$**	magnesium iodide
7.	$CoCl_{2(s)}$	**cobalt(II) chloride**
8.	$TiO_{2(s)}$	**titanium(IV) oxide**
9.	$Cu_2O_{(s)}$	**copper(I) oxide**
10.	**$SnS_{(s)}$**	tin(II) sulfide
11.	**$Cr_2O_{3(s)}$**	chromium(III) oxide
12.	**$FeS_{(s)}$**	iron(II) sulfide
13.	$KC_6H_5COO_{(s)}$	**potassium benzoate**
14.	$Na_2S_2O_{3(s)}$	**sodium thiosulfate**
15.	$NH_4HCO_{3(s)}$	**ammonium hydrogen carbonate**
16.	**$(NH_4)_2S_{(s)}$**	ammonium sulfide
17.	**$BaSO_{3(s)}$**	barium sulfite
18.	**$Mg(OH)_{2(s)}$**	magnesium hydroxide
19.	$FeSO_4 \cdot 7H_2O_{(s)}$	**iron(II) sulfate-7-water or heptahydrate**
20.	$LiCl \cdot 4H_2O_{(s)}$	**lithium chloride-4-water or tetrahydrate**
21.	**$Na_2SO_4 \cdot 10H_2O_{(s)}$**	sodium sulfate decahydrate
22.	$Au(NO_3)_{3(s)}$	**gold(III) nitrate**
23.	**$Bi_2(SO_4)_{3(s)}$**	bismuth(III) sulfate
24.	**$Pb(CH_3COO)_2 \cdot 3H_2O_{(s)}$**	lead(II) acetate-3-water
25.	$KMnO_{4(s)}$	**potassium permanganate**

Molecular Nomenclature

1. List the molecular prefixes from one to ten.

1 **mono**	6 **hexa**
2 **di**	7 **hepta**
3 **tri**	8 **octa**
4 **tetra**	9 nona
5 **penta**	10 **deca**

2. For which type of molecular substances are these prefixes used?

Molecular prefixes are used for binary molecular compounds. Some binary compounds, like water (H_2O) and ammonia (NH_3), preferentially use common names.

3. Why is memorization required for the nomenclature of many molecular substances in this unit?

Memorization is required since neither a theory nor a complete communication system has been presented yet to predict the names and formulas for these compounds.

	Molecular Formula (with SATP state)	English IUPAC Name
4.	**$O_{2(g)}$**	oxygen
5.	$P_2O_{5(s)}$	**diphosphorus pentaoxide**
6.	**$HCl_{(g)}$**	hydrogen chloride
7.	$NH_{3(g)}$	**ammonia**
8.	**$N_2H_{4(l)}$**	dinitrogen tetrahydride (liquid)
9.	$ICl_{5(s)}$	**iodine pentachloride**
10.	**$CH_{4(g)}$**	methane
11.	$NI_{3(s)}$	**nitrogen triiodide**
12.	$CH_3OH_{(l)}$	**methanol**
13.	**$C_{12}H_{22}O_{11(s)}$**	sucrose
14.	$S_4N_{2(s)}$	**tetrasulfur dinitride**
15.	**$C_2H_5OH_{(l)}$**	ethanol
16.	$CO_{(g)}$	**carbon monoxide**
17.	$H_2O_{2(l)}$	**hydrogen peroxide**
18.	$H_2S_{(g)}$	**hydrogen sulfide**
19.	**$S_{8(s)}$**	octasulfur
20.	**$C_3H_{8(g)}$**	propane

MIXED IONIC COMPOUNDS

Complete the *Prediction* section of the following lab report.

Problem

What are the reaction products when various elements react?

Experimental Design

Various elements are reacted and the empirical formulas of the reaction products are determined.

Prediction

According to the theory of ionic compounds, the chemical *formulas* and *names* of the products formed when the following elements react are presented below.

	Reacting Elements	Formula of Product	Name of Product
1.	$Ba_{(s)} + O_{2(g)} \rightarrow$	$BaO_{(s)}$	**barium oxide**
2.	$K_{(s)} + S_{8(s)} \rightarrow$	$K_2S_{(s)}$	**potassium sulfide**
3.	$K_{(s)} + S_{8(s)} + O_{2(g)} \rightarrow$	$K_2SO_{4(s)}$	potassium sulfate
4.	$Ca_{(s)} + P_{4(s)} \rightarrow$	$Ca_3P_{2(s)}$	**calcium phosphide**
5.	$Bi_{(s)} + F_{2(g)} \rightarrow$	$BiF_{3(s)}$	**bismuth(III) fluoride**
6.	$Mg_{(s)} + P_{4(s)} + O_{2(g)} \rightarrow$	$Mg_3(PO_4)_{2(s)}$	magnesium phosphate
7.	$Fe_{(s)} + Se_{(s)} \rightarrow$	$Fe_2Se_{3(s)}$	**iron(III) selenide**
8.	$Sr_{(s)} + N_{2(g)} \rightarrow$	$Sr_3N_{2(s)}$	**strontium nitride**
9.	$Cr_{(s)} + Si_{(s)} + O_{2(g)} \rightarrow$	$Cr_2(SiO_3)_3$	**chromium(III) silicate**
10.	$N_{2(g)} + H_{2(g)} + C_{(s)} + O_{2(g)} \rightarrow$	$(NH_4)_2CO_{3(s)}$	ammonium carbonate

Translate the following equation into an English word equation.

$Fe_{(s)} + S_{8(s)} + O_{2(g)} \rightarrow Fe_2(SO_4)_{3(s)}$

iron + sulfur + oxygen → iron(III) sulfate

ATOMIC THEORY: ATOMS AND IONS

Complete the following table.

	English Name	International Symbol	Number of Protons	Number of Electrons	Number of Electrons Lost or Gained	Net Charge
1.	neon atom	Ne	10	10	0	0
2.	lithium ion	Li^+	3	2	lost 1	1+
3.	silver ion	Ag^+	47	46	lost 1	1+
4.	sulfide ion	S^{2-}	16	18	gained 2	2−
5.	silicon atom	Si	14	14	0	0
6.	arsenide ion	As^{3-}	33	36	gained 3	3−
7.	cesium ion	Cs^+	55	54	lost 1	1+
8.	zinc ion	Zn^{2+}	30	28	lost 2	2+
9.	hydrogen atom	H	1	1	0	0
10.	phosphorus atom	P	15	15	0	0
11.	calcium ion	Ca^{2+}	20	18	lost 2	2+
12.	selenide ion	Se^{2-}	34	36	gained 2	2−
13.	aluminum ion	Al^{3+}	13	10	lost 3	3+
14.	rubidium ion	Rb^+	37	36	lost 1	1+
15.	argon atom	Ar	18	18	0	0
16.	oxide ion	O^{2-}	8	10	gained 2	2−
17.	iodine atom	I	53	53	0	0
18.	plutonium atom	Pu	94	94	0	0
19.	telluride ion	Te^{2-}	52	54	gained 2	2−
20.	unnilseptium atom	Uns	107	107	0	0

Atomic Orbitals and Models

1. Name the four types of orbitals in the sublevels, the number of orbitals in each sublevel, and the maximum number of electrons in that sublevel.

   s, 1 orbital, 2 electrons
   p, 3 orbitals, 6 electrons
   d, 5 orbitals, 10 electrons
   f, 7 orbitals, 14 electrons

2. State Hund's rule.

   No electron pairing takes place in p, d, or f orbitals until each orbital of the given set contains one electron.

3. Write the full electron configurations for each of the following.

   (a) aluminum atom $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

   (b) cobalt atom $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$

   (c) phosphide ion $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

4. What is the "kernel method" for writing electron configurations?

   It is an abbreviation of the electronic configuration of the atom an element using, as a starting point, the electron configuration of the atom of the noble gas element that immediately precedes the element in the periodic table.

5. Write the chemical symbols for the atoms corresponding to the following descriptions.

   (a) [Ar] $4s^2$ Ca

   (b) [Kr] $5s^2\ 4d^{10}\ 5p^1$ In

   (c) [Xe] $6s^2\ 4f^{14}\ 5d^5$ Re

6. List the chemical symbols and names for six ions isoelectronic with an argon atom.

P^{3-}	**phosphide ion**	K^+	**potassium ion**
S^{2-}	**sulfide ion**	Ca^{2+}	**calcium ion**
Cl^-	**chloride ion**	Sc^{3+}	**scandium(III) ion**

7. What is the similarity among the atoms of Group 16 in terms of

   (a) electron configurations

   All atoms have a configuration that ends with $ns^2\ np^4$.

   (b) Lewis models

   All atoms have two lone pairs of electrons and two bonding electrons.

Applications of Stoichiometry

1. In a chemical analysis to test the purity of a bottle of sodium bromide, a solution containing 1.17 g of sodium bromide was reacted with an excess of dimercury(I) acetate solution. The dry precipitate had a mass of 2.73 g. Calculate the percent yield for the precipitate and comment on the purity of sodium bromide.

$$2\,NaBr_{(aq)} + Hg_2(CH_3COO)_{2(aq)} \rightarrow Hg_2Br_{2(s)} + 2\,NaCH_3COO_{(aq)}$$

1.17 g — m

102.89 g/mol — 560.98 g/mol

$$n_{NaBr} = 1.17\text{ g} \times \frac{1\text{ mol}}{102.89\text{ g}} = 0.0114\text{ mol}$$

$$n_{Hg_2Br_2} = 0.0114\text{ mol} \times \frac{1}{2} = 0.005\,69\text{ mol}$$

$$m_{Hg_2Br_2} = 0.005\,69\text{ mol} \times \frac{560.98\text{ g}}{1\text{ mol}} = 3.19\text{ g}$$

$$\text{or } m_{Hg_2Br_2} = 1.17\text{ g NaBr} \times \frac{1\text{ mol NaBr}}{102.89\text{ g NaBr}} \times \frac{1\text{ mol }Hg_2Br_2}{2\text{ mol NaBr}} \times \frac{560.98\text{ g }Hg_2Br_2}{1\text{ mol }Hg_2Br_2} = 3.19\text{ g}$$

$$\%\text{ yield} = \frac{2.73\text{ g}}{3.19\text{ g}} \times 100 = 85.6\%$$

The purity of the sodium bromide is relatively poor and it is likely a technical grade not a reagent grade (see Figure 7.8, page 261).

2. A solution containing 2.56 g of aluminum nitrate is mixed with a solution containing 1.02 g of ammonium sulfide. Determine the unreacted mass of the excess reagent and the mass of precipitate formed.

$$2\,Al(NO_3)_{3(aq)} + 3(NH_4)_2S_{(aq)} \rightarrow Al_2S_{3(s)} + 6\,NH_4NO_{3(aq)}$$

2.56 g — 1.02 g — m

213.01 g/mol — 68.16 g/mol — 150.14 g/mol

$$n_{Al(NO_3)_3} = 2.56\text{ g} \times \frac{1\text{ mol}}{213.01\text{ g}} = 0.0120\text{ mol}$$

$$n_{(NH_4)_2S} = 1.02\text{ g} \times \frac{1\text{ mol}}{68.16\text{ g}} = 0.0150\text{ mol}$$

If $Al(NO_3)_3$ is the limiting reagent, the amount of $(NH_4)_2S$ required is

$$n_{(NH_4)_2S} = 0.0120\text{ mol} \times \frac{3}{2} = 0.0180\text{ mol}$$

Insufficient $(NH_4)_2S$ is present. Therefore $Al(NO_3)_3$ is the excess reagent and $(NH_4)_2S$ is the limiting reagent.

$$n_{Al(NO_3)_3} = 0.0150\text{ mol} \times \frac{2}{3} = 0.009\,98\text{ mol} \quad \text{(required amount)}$$

$$n_{Al(NO_3)_3} = 0.0120\text{ mol} - 0.009\,98\text{ mol} = 0.0020\text{ mol} \quad \text{(excess amount)}$$

$$m_{Al(NO_3)_3} = 0.0020\text{ mol} \times \frac{213.01\text{ g}}{1\text{ mol}} = 0.43\text{ g excess} \quad \text{(unreacted mass)}$$

$$n_{Al_2S_3} = 0.0150\text{ mol} \times \frac{1}{3} = 0.004\,99\text{ mol}$$

$$m_{Al_2S_3} = 0.004\,99\text{ mol} \times \frac{150.14\text{ g}}{1\text{ mol}} = 0.749\text{ g}$$

$$\text{or } m_{Al_2S_3} = 0.0150\text{ mol }(NH_4)_2S \times \frac{1\text{ mol }Al_2S_3}{3\text{ mol }(NH_4)_2S} \times \frac{150.14\text{ g }Al_2S_3}{1\text{ mol }Al_2S_3} = 0.749\text{ g}$$

Gravimetric Stoichiometry

Complete the following stoichiometric problems. Communicate your problem-solving approach using internationally accepted symbols for elements, quantities, numbers, and units.

1. Calculate the mass of iron(III) oxide (rust) produced by the reaction of 500 g of iron with oxygen from the air.

$$4\,Fe_{(s)} + 3\,O_{2(g)} \rightarrow 2\,Fe_2O_{3(s)}$$

500 g — m

55.85 g/mol — 159.70 g/mol

$$n_{Fe} = 500\text{ g} \times \frac{1\text{ mol}}{55.85\text{ g}} = 8.95\text{ mol}$$

$$n_{Fe_2O_3} = 8.95\text{ mol} \times \frac{2}{4} = 4.48\text{ mol}$$

$$m_{Fe_2O_3} = 4.48\text{ mol} \times \frac{159.70\text{ g}}{1\text{ mol}} = 715\text{ g}$$

$$\text{or } m_{Fe_2O_3} = 500\text{ g Fe} \times \frac{1\text{ mol Fe}}{55.85\text{ g Fe}} \times \frac{2\text{ mol }Fe_2O_3}{4\text{ mol Fe}} \times \frac{159.70\text{ g }Fe_2O_3}{1\text{ mol }Fe_2O_3} = 715\text{ g}$$

2. What mass of precipitate should form if 2.00 g of silver nitrate in solution is reacted with excess sodium sulfide solution?

$$2\,AgNO_{3(aq)} + Na_2S_{(aq)} \rightarrow Ag_2S_{(s)} + 2\,NaNO_{3(aq)}$$

2.00 g — m

169.88 g/mol — 247.80 g/mol

$$n_{AgNO_3} = 2.00\text{ g} \times \frac{1\text{ mol}}{169.88\text{ g}} = 0.0118\text{ mol}$$

$$n_{Ag_2S} = 0.0118\text{ mol} \times \frac{1}{2} = 0.005\,89\text{ mol}$$

$$m_{Ag_2S} = 0.005\,89\text{ mol} \times \frac{247.80\text{ g}}{1\text{ mol}} = 1.46\text{ g}$$

$$\text{or } m_{Ag_2S} = 2.00\text{ g }AgNO_3 \times \frac{1\text{ mol }AgNO_3}{169.88\text{ g }AgNO_3} \times \frac{1\text{ mol }Ag_2S}{2\text{ mol }AgNO_3} \times \frac{247.80\text{ g }Ag_2S}{1\text{ mol }Ag_2S} = 1.46\text{ g}$$

3. Determine the mass of water vapor formed when 1.00 g of butane, $C_4H_{10(g)}$, is burned in a lighter.

$$2\,C_4H_{10(g)} + 13\,O_{2(g)} \rightarrow 8\,CO_{2(g)} + 10\,H_2O_{(g)}$$

1.00 g — m

58.14 g/mol — 18.02 g/mol

$$n_{C_4H_{10}} = 1.00\text{ g} \times \frac{1\text{ mol}}{58.14\text{ g}} = 0.0172\text{ mol}$$

$$n_{H_2O} = 0.0172\text{ mol} \times \frac{10}{2} = 0.0860\text{ mol}$$

$$m_{H_2O} = 0.0860\text{ mol} \times \frac{18.02\text{ g}}{1\text{ mol}} = 1.55\text{ g}$$

$$\text{or } m_{H_2O} = 1.00\text{ g }C_4H_{10} \times \frac{1\text{ mol }C_4H_{10}}{58.14\text{ g }C_4H_{10}} \times \frac{10\text{ mol }H_2O}{2\text{ mol }C_4H_{10}} \times \frac{18.02\text{ g }H_2O}{1\text{ mol }H_2O} = 1.55\text{ g}$$

4. Silver metal can be recovered from waste silver nitrate solutions by reaction with copper metal. What mass of silver can be obtained using 50 g of copper?

$$2\,AgNO_{3(aq)} + Cu_{(s)} \rightarrow 2\,Ag_{(s)} + Cu(NO_3)_{2(aq)}$$

50 g — m

63.55 g/mol — 107.87 g/mol

$$n_{Cu} = 50\text{ g} \times \frac{1\text{ mol}}{63.55\text{ g}} = 0.79\text{ mol}$$

$$n_{Ag} = 0.79\text{ mol} \times \frac{2}{1} = 1.6\text{ mol}$$

$$m_{Ag} = 1.6\text{ mol} \times \frac{107.87\text{ g}}{1\text{ mol}} = 0.17\text{ kg}$$

$$\text{or } m_{Ag} = 50\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.55\text{ g Cu}} \times \frac{2\text{ mol Ag}}{1\text{ mol Cu}} \times \frac{107.87\text{ g Ag}}{1\text{ mol Ag}} = 0.17\text{ kg}$$

Solution Preparation

Communicate your problem-solving approach when answering the questions below.

1. Calculate the molar concentration of a solution made by dissolving 20.0 g of sodium hydroxide to make 300 mL of solution.

$$n_{NaOH} = 20.0\ g \times \frac{1\ mol}{40.00\ g} = 0.500\ mol$$

$$C_{NaOH} = \frac{0.500\ mol}{0.300\ L} = 1.67\ mol/L$$

2. Pure sodium thiosulfate-5-water, $Na_2S_2O_3 \cdot 5H_2O_{(s)}$, is used to make 250 mL of 20.0 mmol/L solution. Find the mass of solute required.

$$n_{Na_2S_2O_3 \cdot 5H_2O} = 0.250\ L \times \frac{20.0\ mmol}{1\ L} = 5.00\ mmol$$

$$m_{Na_2S_2O_3 \cdot 5H_2O} = 5.00\ mmol \times \frac{248.20\ g}{1\ mol} = 1.24\ g$$

3. What mass of copper(II) nitrate will be required to prepare 10.0 L of 0.100 mol/L solution?

$$n_{Cu(NO_3)_2} = 10.0\ L \times \frac{0.100\ mol}{1\ L} = 1.00\ mol$$

$$m_{Cu(NO_3)_2} = 1.00\ mol \times \frac{187.57\ g}{1\ mol} = 188\ g$$

4. What volume of 75 mmol/L solution can be prepared from 10 g of sodium carbonate?

$$n_{Na_2CO_3} = 10\ g \times \frac{1\ mol}{105.99\ g} = 94\ mmol$$

$$v_{Na_2CO_3} = 94\ mmol \times \frac{1\ L}{75\ mmol} = 1.3\ L$$

5. Determine the volume of concentrated hydrochloric acid required to prepare 10.0 L of a 0.200 mol/L solution.

$$v_iC_i = v_fC_f$$

$$v_i \times \frac{11.6\ mol}{1\ L} = 10.0\ L \times \frac{0.200\ mol}{1\ L}$$

$$v_i = 0.172\ L$$

6. What volume of concentrated ammonia is required to prepare 2.0 L of a 1.0 mol/L solution?

$$v_iC_i = v_fC_f$$

$$v_i \times \frac{14.8\ mol}{1\ L} = 2.0\ L \times \frac{1.0\ mol}{1\ L}$$

$$v_i = 0.14\ L$$

Concentration of a Solution

Use concentration as a conversion factor to calculate the quantity requested in each question below. Communicate your problem-solving approach, including units and correct certainty.

1. Cow's milk contains 4.5 g of lactose per 100 mL of milk. What mass of lactose is present in 250 mL (one glass) of milk?

$$m_{lactose} = 250\ mL \times \frac{4.5\ g}{100\ mL} = 11\ g$$

2. A 10% W/V salt solution is used for making pickles. What mass of salt is present in 750 mL of this solution?

$$m_{NaCl} = 750\ mL \times \frac{10\ g}{100\ mL} = 75\ g$$

3. A 250 mL measuring cup of cleaning solution contains 1.2 mol of dissolved ammonia. What is the molar concentration of this solution?

$$C_{NH_3} = \frac{1.2\ mol}{0.250\ L} = 4.8\ mol/L$$

4. Fish require a concentration of about 4.5 ppm (4.5 mg/L) of dissolved oxygen in water. What volume of water would contain 100 mg of oxygen?

$$v_{H_2O} = 100\ mg \times \frac{1\ L}{4.5\ mg} = 22\ L$$

5. What volume of concentrated, 14.6 mol/L phosphoric acid would contain 2.00 mol of solute?

$$v_{H_3PO_4} = 2.00\ mol \times \frac{1\ L}{14.6\ mol} = 0.137\ L$$

6. Hard water contains at least 120 ppm of dissolved minerals. If 2.0 L of hard water in a kettle is boiled to dryness, what mass of minerals would be obtained?

$$m_{minerals} = 2.0\ L \times \frac{120\ mg}{1\ L} = 0.24\ g$$

7. What amount of table salt is needed to prepare 12.0 L of a 5.20 mol/L solution?

$$n_{NaCl} = 12.0\ L \times \frac{5.20\ mol}{1\ L} = 62.4\ mol$$

8. A laboratory solution of zinc nitrate is labelled 24.0 mmol/L. What volume of this solution would contain 0.600 mol of solute?

$$v_{Zn(NO_3)_2} = 0.600\ mol \times \frac{1\ L}{24.0\ mmol} \times \frac{1000\ mmol}{1\ mol} = 25.0\ L$$

Molar Mass and Conversions

1. Determine the molar mass of each of the following substances.

(a) $MgI_{2(s)}$ — 278.11 g/mol
(b) $Al(OH)_{3(s)}$ — 78.01 g/mol
(c) $(NH_4)_2CO_{3(s)}$ — 96.11 g/mol
(d) $CoCl_2 \cdot 6H_2O_{(s)}$ — 237.95 g/mol

2. Convert each of the following masses into an amount in moles of the given substance.

(a) 8.40 g of $NaOH_{(s)}$

$$n_{NaOH} = 8.40\ g \times \frac{1\ mol}{40.00\ g} = 0.210\ mol$$

(b) 4.2 kg of $H_2O_{(l)}$

$$n_{H_2O} = 4.2\ kg \times \frac{1\ mol}{18.02\ g} = 0.23\ kmol$$

3. Convert each of the following amounts into a mass in grams of the given substance.

(a) 0.456 mol of $Al_2(SO_4)_{3(s)}$

$$m_{Al_2(SO_4)_3} = 0.456\ mol \times \frac{342.14\ g}{1\ mol} = 156\ g$$

(b) 0.518 mmol of $CuSO_4 \cdot 5H_2O_{(s)}$

$$m_{CuSO_4 \cdot 5H_2O} = 0.518\ mmol \times \frac{249.71\ g}{1\ mol} = 0.129\ g$$

4. Complete the following table.

Substance	Molar Mass (g/mol)	Mass (g)	Amount (mol)
$CaCl_{2(s)}$	110.98	18.6	0.168
$Al_2O_{3(s)}$	101.96	27.2	0.267
$Mg(OH)_{2(s)}$	58.33	35.00	0.6000
$Na_2CO_3 \cdot 10H_2O_{(s)}$	286.19	42.9	0.150

Hydrocarbon Derivatives

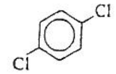
In the following questions, the IUPAC names of a variety of hydrocarbon derivatives are provided. Draw a structural diagram for each name and identify the organic family to which the compound belongs.

1. 2-bromopentane

   Br
   $CH_3-CH-CH_2-CH_2-CH_3$

   organic halide

2. 1,4-dichlorobenzene



   organic halide

3. butanoic acid

   O ‖
   $CH_3-CH_2-CH_2-C-OH$

   carboxylic acid

4. ethyl methanoate

   O ‖
   $H-C-O-CH_2-CH_3$

   ester

5. 1-butanol

   $CH_3-CH_2-CH_2-CH_2-OH$

   alcohol

6. propanal

   O ‖
   CH_3-CH_2-C-H

   aldehyde

7. 1,1-dichloro-2,2-difluoroethane

   Cl F
   $Cl-CH-CH-F$

   organic halide

8. trimethylamine

   CH_3
   CH_3-N-CH_3

   amine

9. 2-methyl-2-propanol

   CH_3
   CH_3-C-CH_3
   OH

   alcohol

10. propanamide

   O ‖
   $CH_3-CH_2-C-NH_2$

   amide

Communicate acceptable English IUPAC names for the following structural models.

11. $CH_3-CH_2-CH-CH_3$
   OH

   2-butanol

12. $Cl-CH_2-CH_2-CH_2-Cl$

   1,3-dichloropropane

13. CH_3-C-OH
   ‖ O

   ethanoic acid
   (acetic acid)

14. $CH_3-C-O-CH_3$
   ‖ O

   methyl ethanoate

Alkanes

For each of the following IUPAC names, draw a structural diagram. *(You may want all hydrogen atoms shown as bonded atoms.)*

1. 2-methylpentane

   CH_3
   $CH_3-CH-CH_2-CH_2-CH_3$

2. 3-ethylhexane

   C_2H_5
   $CH_3-CH_2-CH-CH_2-CH_2-CH_3$

3. 2,3-dimethylbutane

   CH_3
   $CH_3-CH-CH-CH_3$
   CH_3

4. octane

   $CH_3-(CH_2)_6-CH_3$

5. cyclobutane

   CH_2-CH_2
   CH_2-CH_2 or

6. 2,3-dimethylhexane

   CH_3
   $CH_3-CH-CH-CH_2-CH_2-CH_3$
   CH_3

7. trimethylbutane

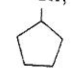
   CH_3 CH_3
   $CH_3-C-CH-CH_3$
   CH_3

8. 3-ethyl-3-methylhexane

   CH_3
   $CH_3-CH_2-C-CH_2-CH_2-CH_3$
   C_2H_5

9. methylcyclopentane

   CH_3



10. 2,2,3-trimethylpentane

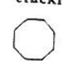
   CH_3 CH_3
   $CH_3-C-CH_2-CH-CH_3$
   CH_3

For each of the following questions, draw a structural diagram equation and classify the reaction type.

11. heptane burns in a fuel mixture
   complete combustion

   $CH_3-(CH_2)_5-CH_3 + O=O \rightarrow O=C=O + H-O-H$

12. cyclooctane + hydrogen → propane + pentane
   cracking



   $+ H-H \rightarrow CH_3-CH_2-CH_3 + CH_3-CH_2-CH_2-CH_2-CH_3$

13. butane + propane → 2,3-dimethylpentane + hydrogen
   reforming

   CH_3
   $CH_3-CH_2-CH_2-CH_3 + CH_3-CH_2-CH_3 \rightarrow CH_3-CH-CH-CH_2-CH_3 + H-H$
   CH_3

Shapes of Molecules

omit

For each of the following molecules, draw an electron dot diagram and use Table 8.? (page 326) to describe the shape around each central atom. Then draw a structural diagram for each. Your predictions can be tested using a molecular model kit.

1. hydrogen iodide, HI

   H:Ï: H – I

   linear

2. silane, SiH_4

   H:Si:H (with H above and below) H – Si (H, H, H)

   tetrahedral

3. phosphine, PH_3

   H:P̈:H (H below) P (H H H)

   pyramidal

4. formaldehyde, H_2CO

   H:C::Ö: (H above) H, H – C = O

   trigonal planar

5. hydrogen peroxide, H_2O_2

   H:Ö:Ö:H H – O – O – H

   V-shaped around each oxygen

6. carbon dioxide, CO_2

   :Ö::C::Ö: O = C = O

   linear

7. hydrazine, N_2H_4

   H:N̈:N̈:H (H H below) H H N – N H H

   pyramidal around each nitrogen

8. propane, C_3H_8

   H H H / H:C:C:C:H / H H H (C – C – C with H atoms)

   tetrahedral around each carbon

9. methylcyanide, CH_3CN

   H:C:C:::N: (H above and below) H – C – C ≡ N (H, H)

   tetrahedral (methyl carbon) **linear (cyanide carbon)**

10. nitrosyl chloride, NOCl

   :Ö::N:C̈l: O = N – Cl

   V-shaped