

Topic 1 Quantitative Chemistry

≡ Essentials ≡

1.) 12-g Carbon-12 = 1 mol = 6.02×10^{23}

The "relative molecular mass" (M_r)
is based on this definition
and has no units.

↑
i.e., molar
mass w/o units!

2.) $1 \text{ dm}^3 = 1000 \text{ cm}^3 = 1000 \text{ mL} = 1 \text{ L}$

Concentration = Molarity = $\frac{\text{mol}}{\text{L}} = \text{mol} \cdot \text{dm}^{-3}$

Density = $\frac{\text{g}}{\text{cm}^3} = \text{g} \cdot \text{cm}^{-3}$

3.) Gases

$$pV = nRT \quad \text{Kelvins}$$

↑ ↑ ↑ ↑
kPa dm³ mol 8.31

$$K = ^\circ\text{C} + 273$$

@ STP (273 K, 100 kPa)
1 mol gas = 22.7 dm³

Note: $M_r = \frac{\text{mass}}{\text{mol}} = \frac{m}{n}$

$$n = \frac{m}{M_r}$$

∴ $pV = \left(\frac{m}{M_r}\right)RT$

or

$$M_r = \frac{mRT}{pV}$$

Key →

IB QUESTIONS – QUANTITATIVE CHEMISTRY

- What is the mass in grams of one molecule of ethanoic acid CH_3COOH ?
A. 0.1 B. 3.6×10^{25} C. 1×10^{-22} D. 60
- Which is not a true statement?
A. One mole of methane contains four moles of hydrogen atoms
B. One mole of ^{12}C has a mass of 12.00 g
C. One mole of hydrogen gas contains 6.02×10^{23} atoms of hydrogen
D. One mole of methane contains 75% of carbon by mass
- A pure compound contains 24 g of carbon, 4 g of hydrogen and 32 g of oxygen.
No other elements are present. What is the empirical formula of the compound?
A. $\text{C}_2\text{H}_4\text{O}_2$ B. CH_2O C. CH_4O D. CHO
- Which one of the following statements about SO_2 is/are correct?
I. One mole of SO_2 contains 1.8×10^{24} atoms
II. One mole of SO_2 has a mass of 64 g
A. Both I and II B. Neither I nor II C. I only D. II only
- What is the empirical formula for the compound $\text{C}_6\text{H}_5(\text{OH})_2$?
A. $\text{C}_6\text{H}_6\text{O}$ B. $\text{C}_6\text{H}_5\text{O}_2\text{H}_2$ C. $\text{C}_6\text{H}_7\text{O}$ D. $\text{C}_6\text{H}_7\text{O}_2$
- Phosphorus burns in oxygen to produce phosphorus pentoxide P_4O_{10} .
What is the sum of the coefficients in the balanced equation?
 $_ \text{P}_4(\text{s}) + _ \text{O}_2(\text{g}) \rightarrow _ \text{P}_4\text{O}_{10}(\text{s})$
A. 3 B. 5 C. 6 D. 7
- Magnesium reacts with hydrochloric acid according to the following equation:
 $\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$
What mass of hydrogen will be obtained if 100 cm^3 of 2.00 mol dm^{-3} HCl are added to 4.86 g of magnesium?
A. 0.2g B. 0.4g C. 0.8g D. 2.0g
- Butane burns in oxygen according to the equation below.
 $2\text{C}_4\text{H}_{10}(\text{g}) + 13\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 10\text{H}_2\text{O}(\text{l})$
If 11.6 g of butane is burned in 11.6 g of oxygen which is the limiting reagent?
A. Butane C. Neither
B. Oxygen D. Oxygen and butane
- When 250 cm^3 of 3.00 mol dm^{-3} $\text{HCl}(\text{aq})$ is added to 350 cm^3 of 2.00 mol dm^{-3} $\text{HCl}(\text{aq})$ the concentration of the solution of hydrochloric acid obtained in mol dm^{-3} is:
A. 2.42 B. 1.45 C. 2.90 D. 2.50
- Sulfuric acid and sodium hydroxide react together according to the equation:
 $\text{H}_2\text{SO}_4(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
What volume of $0.250 \text{ mol dm}^{-3}$ NaOH is required to neutralise exactly 25.0 cm^3 of $0.125 \text{ mol dm}^{-3}$ H_2SO_4 ?
A. 25.0 cm^3 B. 12.5 cm^3 C. 50 cm^3 D. 6.25 cm^3
- Separate samples of two gases, each containing a pure substance, are found to have the same density under the same conditions of temperature and pressure. Which statement about these two samples **must** be correct?
A. They have the same volume
B. They have the same relative molecular mass
C. There are equal numbers of moles of gas in the two samples
D. They condense at the same temperature
- Which expression represents the density of a gas sample of relative molar mass, M_r , at temperature T , and pressure, P ?
A. $\frac{PM_r}{T}$ C. $\frac{PM_r}{RT}$
B. $\frac{RT}{PM_r}$ D. $\frac{RM_r}{PT}$
- A 250 cm^3 sample of an unknown gas has a mass of 1.42 g at 35°C and 0.85 atmospheres. Which expression gives its molar mass, M_r ? ($R = 82.05 \text{ cm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$)
A. $\frac{1.42 \times 82.05 \times 35}{0.25 \times 0.85}$ C. $\frac{1.42 \times 250 \times 0.85}{82.05 \times 308}$
B. $\frac{1.42 \times 82.05 \times 308}{0.25 \times 0.85}$ D. $\frac{1.42 \times 82.05 \times 308}{250 \times 0.85}$
- Aspirin, $\text{C}_9\text{H}_8\text{O}_4$, is made by reacting ethanoic anhydride, $\text{C}_4\text{H}_6\text{O}_3$ ($M_r = 102.1$), with 2-hydroxybenzoic acid ($M_r = 138.1$), according to the equation:
 $2\text{C}_7\text{H}_6\text{O}_3 + \text{C}_4\text{H}_6\text{O}_3 \rightarrow 2\text{C}_9\text{H}_8\text{O}_4 + \text{H}_2\text{O}$
(a) If 15.0 g 2-hydroxybenzoic acid is reacted with 15.0 g ethanoic acid, determine the limiting reagent in this reaction.
(b) Calculate the maximum mass of aspirin that could be obtained in this reaction.
(c) If the mass obtained in this experiment was 13.7 g, calculate the percentage yield of aspirin.
- 14.48 g of a metal sulfate with the formula M_2SO_4 were dissolved in water. Excess barium nitrate solution was added in order to precipitate all the sulfate ions in the form of barium sulfate. 9.336 g of precipitate was obtained.
(a) Calculate the amount of barium sulfate BaSO_4 precipitated.
(b) Calculate the amount of sulfate ions present in the 14.48 g of M_2SO_4 .
(c) What is the relative molar mass of M_2SO_4 ?
(d) Calculate the relative atomic mass of M and hence identify the metal.

ch 1 Quantitative Chemistry Key

1.) C



$$\text{molar mass} = 2(12.01) + 2(16.00) + 4(1.01) = 60.06 \text{ g}$$

$$\frac{60.06 \text{ g}}{\text{mol}} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} = 9.977 \times 10^{-23} \frac{\text{g}}{\text{molec.}}$$

($\approx 1 \times 10^{-22}$)

2.) C

Hydrogen is diatomic, H_2 !

$$\text{so, } 2(6.02 \times 10^{23} \text{ atoms}) = 1.204 \times 10^{24} \text{ atoms H}$$

3.) B

$$24 \text{ g C} \times \frac{1 \text{ mol}}{12.01} = 2.0 \text{ mol C}$$

$$4 \text{ g H} \times \frac{1 \text{ mol}}{1.01} = 4 \text{ mol H}$$

$$32 \text{ g O} \times \frac{1 \text{ mol}}{16.00} = 2 \text{ mol O}$$



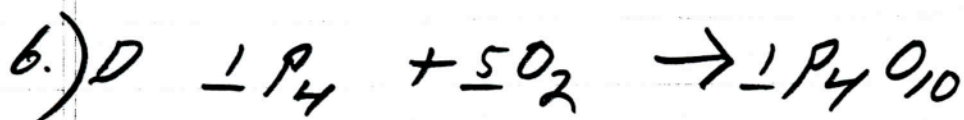
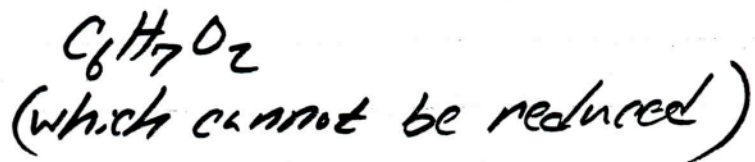
4.) A

i) $3(6.02 \times 10^{23}) = 1.8 \times 10^{24} \text{ atoms True!}$

ii) $(32.06 \text{ g}) + 2(16.00 \text{ g}) = 64 \text{ g True!}$

5.) D

rewrite $C_6H_5(OH)_2$ as



$$1 + 5 + 1 = \boxed{7}$$

7.) A

$$4.86g Mg \times \frac{1 mol}{24.31g} \times \frac{1 mol H_2}{1 mol Mg} \times \frac{2.02g H_2}{1 mol} = 0.403g H_2$$

$$(0.100L HCl) \left(2.00 \frac{mol}{L} \right) \times \frac{1 mol H_2}{2 mol HCl} \times \frac{2.02g}{1 mol} = \boxed{0.202g H_2}$$

$$\left[\text{recall } \frac{mol}{mol} = \frac{mol}{L} \right]$$

↑
Least amount

8.) B

Note: only need to determine the L.R.

$$11.6g C_4H_{10} \times \frac{1 mol}{58.14g} \times \frac{13 mol O_2}{2 mol C_4H_{10}} \times \frac{32.00g}{1 mol O_2}$$

$$= 41.5g O_2 \text{ needed.}$$

But you only have 11.6g O_2 , $\therefore O_2$ is L.R.

9.) A

First, determine the number of moles HCl present in each solution.

$$(0.250\text{L})(3.00\text{M}) = 0.750\text{mol}$$

$$(0.350\text{L})(2.00\text{M}) = 0.700\text{mol}$$

Then determine concentration

$$[\text{HCl}]_{\text{final}} = \frac{(0.750 + 0.700)\text{mol}}{(0.250 + 0.350)\text{L}} = 2.42\text{M}$$

10.) A

$$(0.025\text{L})\left(0.125 \frac{\text{mol H}_2\text{SO}_4}{\text{L}}\right) \times \frac{2\text{mol NaOH}}{1\text{mol H}_2\text{SO}_4} = 0.00625\text{mol NaOH}$$

$$M = \frac{\text{mol}}{\text{L}} \rightarrow L = \frac{\text{mol}}{M}$$

$$L = \frac{0.00625\text{mol}}{0.250\text{M}} = 0.0250\text{L} \\ = 25.0\text{mL} \\ (25\text{cm}^3)$$

11.) B

(see #12 below first!)

$$d_1 = d_2$$

$$P_1 = P_2$$

$$T_1 = T_2$$

($M = \text{molecular mass}$)

$$\therefore \frac{P_1 M_1}{RT_1} = \frac{P_2 M_2}{RT_2}$$

$$M_1 = M_2$$

12.) C

$$n = \frac{\text{mass}}{M}$$

$$PV = nRT$$

or

$$PV = \left(\frac{m}{M}\right) RT$$

$$\text{density} = \frac{m}{V} = \left[\frac{PM}{RT} \right]$$

13.) D From problem 12,

$$PV = \frac{nRT}{M}$$

$$M = \frac{nRT}{VP} = \frac{(1.42)(82.05)(308)}{(250)(0.85)}$$

$T = 35 + 273$
↓
(308)

14.) a.) $15.0g C_7H_6O_3 \times \frac{1mol}{138.13g} \times \frac{1mol C_4H_6O_3}{2mol C_7H_6O} \times \frac{102.10g}{1mol} =$

5.54g $C_4H_6O_3$
Required

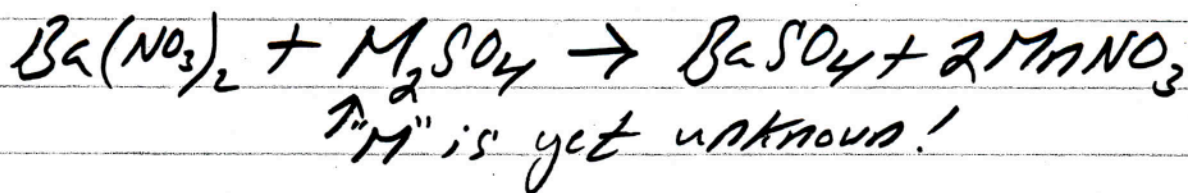
$\therefore C_7H_6O_3$ is L.R.
(2-hydroxybenzoic acid)

b.) $15.0g C_7H_6O_3 \times \frac{1mol}{138.13g} \times \frac{2mol C_9H_8O_4}{2mol C_7H_6O} \times \frac{180.17g}{1mol}$
L.R. \rightarrow

$= 19.6g C_9H_8O_4$

c.) $\frac{13.7g}{19.6g} \times 100 = 69.9\%$

15.) Need a balanced chemical equation -



a.) By "amount", they mean moles.

$$9.336 \text{ g BaSO}_4 \times \frac{1 \text{ mol}}{233.4 \text{ g}} = \boxed{0.04000 \text{ mol BaSO}_4}$$

b.) Since "excess" $\text{Ba}(\text{NO}_3)_2$ was added, you can assume SO_4^{2-} is L.R.

$$0.04000 \text{ mol BaSO}_4 \times \frac{1 \text{ mol SO}_4^{2-}}{1 \text{ mol BaSO}_4} = \boxed{0.04000 \text{ mol SO}_4^{2-}}$$

$$c.) M_r = \frac{\text{mass}}{\text{moles}} = \frac{14.48}{0.04000} = \boxed{362}$$

recall M_r has no units

d.) M_2SO_4 molar mass = 362 (from above)

$$2(\text{atomic mass of M}) + (32.06) + 4(16.00) = 362$$

$$\text{atomic mass of M} = \frac{362 - (32.06) - 4(16.00)}{2} = 133$$

$\therefore \boxed{\text{Cs}}$