Practice →

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.) $1\ dm^3 = 1000\ cm^3 = 1000\ mL = 1\ L$

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

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

3.) Gases

$$PV = nRT \quad \text{(T in Kelvins)}$$

P: kPa, V: dm^3, n: mol, R: 8.31

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

@ STP (273 K, 100 kPa)

1 mol gas = $22.7\ dm^3$

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

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

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

or

$$\boxed{M_r = \frac{mRT}{PV}}$$

Key →

IB QUESTIONS – QUANTITATIVE CHEMISTRY

1. 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

2. 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

3. 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. $C_2H_4O_2$ **B.** CH_2O **C.** CH_4O **D.** CHO

4. 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

5. What is the empirical formula for the compound $C_6H_5(OH)_2$?

   A. C_6H_6O **B.** $C_6H_5O_2H_2$ **C.** C_6H_7O **D.** $C_6H_7O_2$

6. Phosphorus burns in oxygen to produce phosphorus pentoxide P_4O_{10}.

   What is the sum of the coefficients in the balanced equation?

   $\_P_4(s) + \_O_2(g) \rightarrow \_P_4O_{10}(s)$

   A. 3 **B.** 5 **C.** 6 **D.** 7

7. Magnesium reacts with hydrochloric acid according to the following equation:

   $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

   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

8. Butane burns in oxygen according to the equation below.

   $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

   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

9. When 250 cm^3 of 3.00 mol dm^{-3} HCl(aq) is added to 350 cm^3 of 2.00 mol dm^{-3} HCl(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

10. Sulfuric acid and sodium hydroxide react together according to the equation:

    $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

    What volume of 0.250 mol dm^{-3} NaOH is required to neutralise exactly 25.0 cm^3 of 0.125 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

11. 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

12. 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.** $\frac{RM_r}{PT}$

13. 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? ($R = 82.05$ cm^3 atm K^{-1} 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.** $\frac{1.42 \times 82.05 \times 308}{250 \times 0.85}$

14. Aspirin, $C_9H_8O_4$, is made by reacting ethanoic anhydride, $C_4H_6O_3$ ($M_r = 102.1$), with 2-hydroxybenzoic acid ($M_r = 138.1$), according to the equation:

    $2C_7H_6O_3 + C_4H_6O_3 \rightarrow 2C_9H_8O_4 + H_2O$

    (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.

15. 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.

Key

Ch 1 Quantitative Chemistry

1.) C

CH_3COOH

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

$$\frac{60.06\ g}{mol} \times \frac{1\ mol}{6.02\times10^{23}\ molecules} = 9.977\times10^{-23}\ g/molec.$$
$$(\approx 1\times10^{-22})$$

2.) C

Hydrogen is diatomic, H_2!

So, $2(6.02\times10^{23}\ atoms) = 1.204\times10^{24}\ atoms\ H$

3.) B $\quad 24g\,C \times \frac{1\ mol}{12.01} = 2.0\ mol\ C$

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

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

$\boxed{CH_2O}$

4.) A

i) $3(6.02\times10^{23}) = 1.8\times10^{24}$ atoms True!

ii) $(32.06g) + 2(16.00g) = 64g$ True!

5.) D

Rewrite $C_6H_5(OH)_2$ as

$C_6H_7O_2$

(which cannot be reduced)

6.) D $1P_4 + 5O_2 \rightarrow 1P_4O_{10}$

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

7.) A

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

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

$\left[\text{Recall } mol\,dm^{-3} = \frac{mol}{L}\right]$

↑ Least amount

8.) B Note: only need to determine the L.R.

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

$= 41.5\,g\,O_2$ needed.

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

9.) A

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

$(0.250\,L)(3.00\,M) = 0.750\,mol$

$(0.350\,L)(2.00\,M) = 0.700\,mol$

Then determine concentration

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

10.) A

$$(0.025\,L)\left(0.125\,\frac{mol\,H_2SO_4}{L}\right) \times \frac{2\,mol\,NaOH}{1\,mol\,H_2SO_4}$$

$$= 0.00625\,mol\,NaOH$$

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

$$L = \frac{0.00625\,mol}{0.250\,M} = 0.0250\,L$$

$$= 25.0\,mL$$

$$(25\,cm^3)$$

11.) B (see #12 Below first!)

$d_1 = d_2$

$P_1 = P_2$ (M = molecular mass)

$T_1 = T_2$

$\therefore \frac{P_1 M_1}{R T_1} = \frac{P_2 M_2}{R T_2}$

$M_1 = M_2$

12.) C $n = \frac{\text{mass}}{M}$

$PV = nRT$

or

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

$\text{density} = \frac{m}{V} = \boxed{\frac{PM}{RT}}$

13.) D From problem 12,

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

$T = 35 + 273$

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

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

$5.54\,g\ C_4H_6O_3$ Required

$\therefore C_7H_6O_3$ is L.R.

(2-hydroxybenzoic acid)

b.) L.R. $15.0\,g\ C_7H_6O_3 \times \frac{1\,mol}{138.13\,g} \times \frac{2\,mol\ C_9H_8O_4}{2\,mol\ C_7H_8O} \times \frac{180.17\,g}{1\,mol}$

$= \boxed{19.6\,g\ C_9H_8O_4}$

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

15.) Need a balanced chemical equation –

$$Ba(NO_3)_2 + M_2SO_4 \rightarrow BaSO_4 + 2MnNO_3$$

"M" is yet unknown!

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

$$9.336\,g\ BaSO_4 \times \frac{1\,mol}{233.40\,g} = \boxed{0.04000\ mol\ BaSO_4}$$

b.) Since "excess" $Ba(NO_3)_2$ was added, you can assume SO_4^{2-} is L.R.

$$0.04000\ mol\ BaSO_4 \times \frac{1\,mol\ SO_4^{2-}}{1\,mol\ BaSO_4} = \boxed{0.04000\ mol\ SO_4^{2-}}$$

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

Recall M_r has no units

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

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

(32.06) ↑ S; 4(16.00) ↑ O

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

$\therefore$ $\boxed{Cs}$