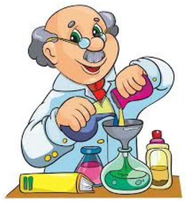
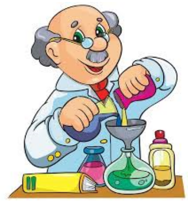
# MOLES Test ANSWERS



# Moles Test

No.1



To Pass the Mole Test you will need to achieve a score of greater than 70%. Each question is equally weighted (5%).

**Relative Atomic Masses:**
Hydrogen (H) = 1, Carbon (C) = 12, Nitrogen (N) = 14, Oxygen (O) = 16, Sodium (Na) = 23, Sulfur (S) = 32, Chlorine (Cl) = 35.5, Potassium (39), Calcium (Ca) = 40, Copper (Cu) = 63.5, Barium (Ba) = 137, Mercury(Hg) 200.5, Lead (Pb) = 207

**Molar Volume:** 22.4 $dm^3$ or 22,4000 $cm^3$ at STP (273.15 K and 1 atm)

**Avodagdro's Number:** 6.02 x $10^{23}$

1. Rubidium is a soft, silvery-white metal that has two common isotopes, $^{85}Rb$ and $^{87}Rb$. If the abundance of $^{85}Rb$ is 72.2% and the abundance of $^{87}Rb$ is 27.8%, what is the average atomic mass of rubidium?

   *Answer:*
   Average Atomic Mass = (72.2/100 x 85) + (27.8/100 x 87)
   = 61.37 + 24.186
   = 85.56

2. An unknown compound was found to have a percent composition as follows: 47.0 % potassium, 14.5 % carbon, and 38.5 % oxygen. What is its empirical formula? If the true molar mass of the compound is 166.22 g $mol^{-1}$, what is its molecular formula?

   *Answer:*

| | Potassium | Carbon | Oxygen |
|---|---|---|---|
| % composition | 47.0 | 14.5 | 38.5 |
| Ar | 39 | 12 | 16 |
| % composition/Ar | 47/39 = 1.2 | 14.5/12 = 1.2 | 38.5/16 = 2.4 |
| Ratio | 1 | 1 | 2 |

Empirical formula: $KCO_2$
Relative formula mass $KCO_2$ = (1 x 39) + 12 + (2 x 16) = 83
Molecular formula = $(KCO_2)_n$
n = 166/83 = 2
Molecular formula = $(KCO_2)_2 = K_2C_2O_4$

3. Lead (IV) oxide reacts with concentrated hydrochloric acid as follows:

$$PbO_{2(s)} + 4HCl_{(aq)} \rightarrow PbCl_{2(s)} + Cl_{2(g)} + 2H_2O_{(l)}$$

What mass of lead chloride would be obtained from 37.2g of $PbO_2$, and what mass of chlorine gas would be produced?

*Answer:*

| | $PbO_{2(s)}$ | + | $4HCl_{(s)}$ | → | $PbCl_{2(aq)}$ | + | $Cl_{2(g)}$ | + | $2H_2O_{(l)}$ |
|---|---|---|---|---|---|---|---|---|---|
| $M_r$ | 239 | | 36.5 | | 278 | | 71 | | 18 |
| Mass Balance | 239 | | 146 | | 278 | | 71 | | 36 |
| | | 385 | | | | 385 | | | |
| Reaction Coefficients | 1 | | 4 | | 1 | | 1 | | 1 |
| Mass (g) | 37.2 | | | | 0.1556 x 278 = 43.27 | | 0.1556 x 71 = 11.05 | | |
| No. of moles | 347.2/239 = 0.1556 | | | | 0.1556 | | 0.1556 | | |

$M_r$ [$PbO_2$]
$M_r$ [$PbCl_2$]
Number of moles $PbO_2$ in 37.2 g = mass/$M_r$ = 347.2/239 = 0.1556
According to the reaction coefficients – one mole of $PbO_2$ produces one mole $PbCl_2$
Therefore, 0.1556 moles of $PbO_2$ can produce 0.1556 moles $PbCl_2$
Mass of 0.01556 moles of $PbCl_2$ = number of moles x $M_r$ = 0.1556 x 278 = 43.27 g
Mass of $PbCl_2$ = **43.27 g**

According to the reaction coefficients – one mole of $PbO_2$ produces one mole of $Cl_2$
Therefore, 0.1556 moles of $PbO_2$ can produce 0.1556 moles $Cl_2$
Mass of 0.01556 moles of $Cl_2$ = number of moles x $M_r$ = 0.1556 x 71 = 11.05 g
Mass of $Cl_2$ = **11.05 g**

4. In 1774 Joseph Priestly conducted one of his most famous experiments which lead to a method for the preparation of oxygen. The experiment involved heating a sample of mercury II oxide with a large lens.
The equation for this reaction is shown below:

$$2HgO_{(s)} \rightarrow 2Hg_{(l)} + O_{2(g)}$$

What volume of $O_2$(g) would be obtained if 1.08g of mercury (II) oxide were completely decomposed? (Given that 1 mole of a gas occupies 24 $dm^3$ under the experimental conditions)

Answer:

| | $2HgO_{(s)}$ | → | $2Hg_{(l)}$ | + | $O_{2(g)}$ |
|---|---|---|---|---|---|
| $A_r/M_r$ | 216.5 | | 200.5 | | 32 |
| Mass Balance | 433 | | 401 | | 32 |
| | | | | 433 | |
| Reaction Coefficients | 2 | : | 2 | | 1 |
| Mass | 1.08/216.5 = 1.08 | | | | |
| No. of moles | 0.005 | | 0.005 | | 0.0025 |
| Volume ($dm^3$) | | | | | 0.025 x 22.4 = 0.06 |

Mr [HgO] = 216.5

Number of moles of HgO in 1.08 g = 1.08/216.5 = 0.005
According to the reaction coefficients 2 moles of HgO generates one mole O2
Thus number of moles of $O_2$ produced from 0.005 moles HgO = 0.005/2 = 0.0025
Volume of 0.0025 moles = 0.0025 x 24 = 0.06 $dm^3$ = **60 $cm^3$**

5. When copper (II) nitrate is heated, it decomposes according to the following equation:

$$2Cu(NO_3)_{2(s)} \rightarrow 2CuO_{(s)} + 4NO_{2(g)} + O_{2(g)}$$

a) When 20.0g of copper (II) nitrate is heated, what mass of copper (II) oxide would be produced?

*Answer*

| | $2Cu(NO_3)_{2(s)}$ | → | $2CuO_{(s)}$ | + | $4NO_{(g)}$ | + | $O_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 187.5 | | 79.5 | | 46 | | 32 |
| Mass Balance | 375 | | 159 | | 184 | | 32 |
| | | | | 375 | | | |
| Reaction Coefficients | 2 | | 2 | | 4 | | 1 |
| Mass | 20 | | 0.1066 x 79.5 =8.48 | | 0.2013 x 46 =9.8 | | |
| No. of moles | 20/187.5 = 0.1066 | | 0.1066 | | 2 x 0.1066 = 0.2013 | | |

$M_r$ $Cu(NO_3)_2$ = 187.5
$M_r$ CuO = 79.5
$M_r$ $NO_2$ = 46

Number of moles of $Cu(NO_3)_2$ in 20 g = mass/$M_r$ = 20/187.5 = 0.1066
According to the balanced chemical one mole of $Cu(NO_3)_2$ produces one mole CuO
Therefore, 0.1066 moles $Cu(NO_3)_2$ can produce 0.1066 moles CuO
Mass of 0.1066 moles CuO = number of moles x $M_r$ = 0.1066 x 79.5 = 8.48 g
Mass of CuO = **8.48 g**

b) What mass of $NO_2$ would be produced?

*Answer*
According to the reaction coefficients – one mole of $Cu(NO_3)_2$ produces 2 moles $NO_2$
Therefore, 0.1066 moles $Cu(NO_3)_2$ can produce 0.2132 moles (2 x 0.1066) $NO_2$
Mass of 0.2132 moles $NO_2$ = number of moles x $M_r$ = 0.2132 x 46 = 9.8 g
Mass $NO_2$ = **9.8 g**

6. A solution containing 0.732 mol of ammonia was made up to 250 $cm^3$ in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

*Answer*
Covert volume to litres
Volume = 250 $cm^3$ = 0.25 litres
Number of moles of $NH_3$ = 0.732
Concentration = number of moles/volume = 0.732/0.25 = 2.928 M

Concentration of ammonia solution = **2.928 M**

7. Sodium hydride reacts with water according to the following equation.

$$NaH_{(s)} + H_2O_{(l)} \rightarrow NaOH_{(aq)} + H_{2\,(g)}$$

A 1.00 g sample of sodium hydride was added to water and the resulting solution was diluted to a volume of exactly 250 cm$^3$.

a) Calculate the concentration in moldm$^{-3}$, of sodium hydroxide solution formed.

*Answer*

| | $NaH_{(aq)}$ | + | $H_2O_{(l)}$ | → | $NaOH_{(aq)}$ | + | $H_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 24 | | 18 | | 40 | | 2 |
| Mass Balance | | | | | | | |
| Reaction Coefficients | 1 | | 1 | | 1 | | 1 |
| Mass | 1 | | | | | | |
| No. of moles | 1/24 = 0.01417 | | | | | | 0.01417 |
| Volume (L) | 0.25 | | | | | | 0.01417 x 22.4 = 0.934 |
| Concentration (M) | | | | | | | 0.01417/0.25 = 0.167 |

$M_r$ [NaH] = 24
Number of moles of NaH in 1 g = 1/24 = 0.01417
According to the reaction coefficients – one mole of NaH produces 1 mole NaOH
Thus number of moles of NaOH produced from 0.01417 moles NaH = 0.01417
Volume = 250 cm$^3$ = 0.25 dm$^3$
Concentration = number of moles/volume = 0.01417/0.25
Concentration of NaOH = **0.167M**

b) the volume of hydrogen gas evolved, measured at STP.

*Answer*
According to the balanced equation, one mole of NaH will produce I mole of $H_2$
Therefore, 0.01417 moles NaH will generate 0.01417 moles $H_2$
Given that one mole of gas occupies a volume of 22,400 cm$^3$ at STP
Therefore, 0.01417 moles $H_2$ will occupy a volume of 0.0417 x 22.4 = **0.934 dm$^3$**

c) Calculate the volume of 0.112 M hydrochloric acid which would react exactly with a 25.0 cm$^3$ sample of sodium hydroxide solution

*Answer:*

| | $NaOH_{(aq)}$ | + | $HCl_{(aq)}$ | → | $NaCl + H_2O$ |
|---|---|---|---|---|---|
| Volume (cm$^3$) | 25 | | 4.175 x 10$^{-3}$ x 1000/0.112 = 37.28 | | |

| | | | |
|---|---|---|---|
| Moles | 25/1000 x 0.167 = 4.175 x $10^{-3}$ | | 4.175 x $10^{-3}$ |
| Concentration (M) | 0.167 | | 0.112 |
| Reaction coefficientss | 1 | : | 1 |

Number of moles in 25 $cm^3$ NaOH of concentration 0.167M = 25/1000 x 0.167 = 4.175 x $10^{-3}$
According to the reaction coefficients, 1 mole of NaOH reacts with 1 mole HCl
Therefore the number of moles HCl that reacted exactly with 4.175 x $10^{-3}$ moles NaOH = 4.175 x $10^{-3}$
Volume of 0.112M containing 4.175 x $10^{-3}$ moles HCl $cm^3$ = 4.175 x $10^{-3}$ x 1000/0.112 = **37.28 $cm^3$**

8. Sodium carbonate forms a number of hydrates of general formula $Na_2CO_3.xH_2O$. A 3.01 g sample of one of these hydrates was dissolved in water and the solution made up to 250 $cm^3$. In a titration, a 25.0 $cm^3$ portion of this solution required 24.3 $cm^3$ of 0.200 M hydrochloric acid for complete reaction.

The equation for this reaction is shown below.

$$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

a) Calculate the number of moles of HCl in 24.3 $cm^3$ of 0.200 M hydrochloric acid.

*Answer:*

| | $Na_2CO_{3(aq)}$ | + | $2HCl_{(aq)}$ | $\rightarrow$ | $2NaCl + CO_2 + H_2O$ |
|---|---|---|---|---|---|
| Volume ($cm^3$) | 25 | | 24.3 | | |
| No. of moles | 4.86 x $10^{-3}$ /2 = 2.42 x $10^{-3}$ | | 24.3/1000 x 24.3 = 4.86 x $10^{-3}$ | | |
| Concentration (M) | 1000/25 x 2.43 x $10^{-3}$ = 0.0972 | | 0.2 | | |
| Reaction coefficients | 1 | | 2 | | |

Number of moles in 24.3 $cm^3$ of 0.200 M HCl = volume x concentration = 24.3/1000 x 0.200 = **4.86 x $10^{-3}$**

b) Deduce the number of moles of $Na_2CO_3$ in 25.0 $cm^3$ of the $Na_2CO_3$ solution.

*Answer:*
According to the reaction coefficients, at the end point, the number of moles $Na_2CO_3$ = 0.5 x number of moles of HCl
Therefore number of moles of $Na_2CO_3$ in 25.0 $cm^3$ of the $Na_2CO_3$ solution = 0.5 x 4.86 x $10^{-3}$ = **2.43 x $10^{-3}$**

c) Hence deduce the number of moles of $Na_2CO_3$ in the original 250 $cm^3$ of solution.

*Answer*
If number of moles of $Na_2CO_3$ present in 25 $cm^3$, concentration of the solution (ie the number of moles in 1000$cm^3$) = 1000/25 x 2.43 x $10^{-3}$ = **0.0972 M**

d) Calculate the $M_r$ of the hydrated sodium carbonate

*Answer*

Number of moles of $Na_2CO_3xH_2O$ in 250 $cm^3$ = 0.0243
Mass of 0.0243 moles of $Na_2CO_3xH_2O$ = 3.01 g
$M_r$ [$Na_2CO_3xH_2O$] = 1/0.0243 x 3.01 = 123.9
Since $M_r$ [$Na_2CO_3$] =106
$M_r$ [$xH_20$] = 18; therefore x = **1**

9. A student knew adding calcium to water could make that calcium hydroxide. The student added 0.00131 mol of calcium to a beaker containing about 100 $cm^3$ of water. A reaction took place as shown by the equation below. All the calcium hydroxide formed was soluble.

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

a) Calculate the mass of calcium that the student added.

*Answer*

| | $Ca_{(s)}$ | + | $2H_2O_{(l)}$ | → | $Ca(OH)_{2(aq)}$ | + | $H_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 40 | | 18 | | 74 | | 2 |
| Mass Balance | 40 | | 2 x 18 = | | 74 | | 2 |
| | | 76 | 36 | | | 76 | |
| Reaction Coefficients | 1 | | 2 | | 1 | | 1 |
| Mass | 0.00131 x 40 = 0.0524 | | | | | | |
| No. of moles | 0.00131 | | | | | | 0.0131 |
| Volume ($cm^3$) | | | | | | | 0.00131 x 22400 = 29.3 |
| Concentration (M) | | | | | | | |

Mass of 0.00131 mole of calcium = number of moles x $M_r$ = 0.00131 x 40 = **0.0524 g**

b) Calculate the volume of hydrogen gas, in $dm^3$, produced in this reaction at standard temperature and pressure, STP.

*Answer*

According to the reaction coefficients, 1 mole Ca produces 1 mole of $H_2$
Thus 0.00131 mole of Ca can generate 0.00131 mole $H_2$
One mole of gas at STP occupies a volume of 22.4 $dm^3$
Thus 0.00131 mole $H_2$ will occupy a volume of 0.00131 x 22400 = **29.3 $cm^3$**

c) The student transferred the contents of the beaker to a 250$cm^3$ volumetric flask and water was added to make the solution up to 250 $cm^3$. Calculate the concentration, in M, of hydroxide ions in the 250 $cm^3$ solution.

*Answer*

According to the balanced chemical equation one mole of Ca will produce one mole $Ca(OH)_2$
Thus 0.00131 mole Ca can generate 0.00131 mole $Ca(OH)_2$
Given that $Ca(OH)_2$ totally dissociates:
$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$

The number of moles of 2OH$^-$ ions in 250 cm$^3$ = 2 x 0.00131 = 0.0262 moles
Concentration of $Ca(OH)_2$ = 1000/250 x 0.0262 = **0.0105M**

10. A 1.0 kg sample of methane was burned in air. It reacted as follows:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

Calculate the volume of oxygen gas, measured at STP, which would be required for the complete combustion of 1.0 kg of methane.

*Answer*

| | $CH_{4(aq)}$ | + | $2O_{2(aq)}$ | → | $CO_{2(g)}$ | + | $2H_2O_{(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 16 | | 32 | | 44 | | 18 |
| Mass Balance | 16 | | 64 | | 44 | | 36 |
| | | 80 | | | | 80 | |
| Reaction Coefficients | 1 | | 2 | | 1 | | 1 |
| Mass (g) | 1000 | | | | | | |
| No. of moles | 1000/16 =62.5 | | 62.5 x 2 = 125 | | | | |
| Volume (dm3) | | | 125 x 22.4 = 2800 | | | | |

$M_r[CH_4]$ = 16
Number of moles of $CH_4$ in 1000 g (1 kg) = 1000/16 = 62.5
According to the balanced chemical equation, 1 mole of $CH_4$ required 2 moles of $O_2$ to be totally combust
Thus 62.5 moles $CH_4$ requires 62.5 x 2 = 125 moles $O_2$ to totally combust
Volume of 125 moles $O_2$ = 22.4 x 125 = **2,800 dm$^3$**

11. When 5.175 g of lead are heated at 300°C the lead reacts with the oxygen in the air to produce 5.708 g of an oxide of lead. This is the only product. What is the equation for this reaction?

*Answer:*

| | $xPb_{(s)}$ | + | $yO_{2(g)}$ | → | $Pb_xO_{y(s)}$ |
|---|---|---|---|---|---|
| $M_r$ | 207 | | 32 | | |
| Mass Balance | | | | | |
| Reaction Coefficients | | | | | |
| Mass | 5.175 | | 5.708-5.175 = 0.533 | | 5.708 |
| No. of moles | 0.025 | | 0.0167 | | |
| Mole Ratio | 1 | | 1.5 | | |

Mass of oxygen consumed in the formation of the lead oxide = 5.708 – 5.175 g = 0.533 g
Number of moles of Pb in 5.175 g = mass/$M_r$ = 5.175/207 = 0.025 moles
Number of moles of $O_2$ consumed = mass/$M_r$ = 0.533/32 = 0.0167 moles
Thus 0.025 moles of Pb react with 0.0167 moles of $O_2$ to give product
Thus 1.5 moles (0.025/0.0167) of Pb react with 1 mole (0.0167/0.0167) of $O_2$ to produce the lead oxide
Therefore, 3 moles of Pb react with 2 moles of $O_2$ to give product

$3Pb + 2O_2 \rightarrow Pb_3O_4$

12. 4.90g of pure sulfuric acid was dissolved in water, the resulting total volume was 200 $cm^3$. 20.7 $cm^3$ of this solution was found on titration, to completely neutralise 10.0 $cm^3$ of a sodium hydroxide solution. [atomic masses: S = 32, O = 16, H = 1]

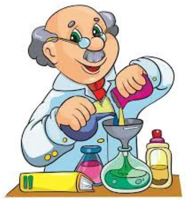
Calculate the concentration of the sodium hydroxide (M)

*Answer:*

| | $H_2SO_{4(aq)}$ | + | $2NaOH_{(aq)}$ | → | $Na_2SO_4 + 2H_2O$ |
|---|---|---|---|---|---|
| Volume ($cm^3$) | 20.7 | | 10 | | |
| No. of moles | 20.7/1000 x 0.25 = 0.0052 | | 2 x 0.0052 = 0.0104 | | |
| Concentration (M) | 0.25 | | 1000/10 x 0.0104 = 1.04 | | |
| Reaction Coefficients | 1 | : | 2 | | |

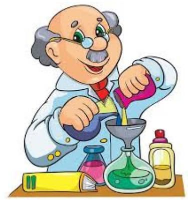
Mr[$H_2SO_4$] = 98
Number of moles $H_2SO4$ in 4.9 g = 4.9/98 = 0.05
Volume = 200 $cm^3$ = 0.2 $dm^3$
Concentration = number of moles /volume = 0.05/0.2 = 0.25M

Number of moles of 0.25M $H_2SO_4$ in 20.4 $cm^3$ = volume x concentration = 20.4/1000 x 0.25 = 0.0052
At the end point, 2 x number of moles of $H_2SO_4$ = number of moles of NaOH in 10 $cm^3$
Thus, the number of moles of NaOH in 10$cm^3$ = 2 x 0.0052 = 0.0104
Concentration of NaOH = 1000/10 x 0.0104 = 1.04M



# Moles Test

## No.2



To Pass the Moles Test you will need to achieve a score of greater than 70%. Each question is equally weighted (5%).

**Relative Atomic Masses:**
Hydrogen (H) = 1, Carbon (C) = 12, Nitrogen (N) = 14, Oxygen (O) = 16, Sodium (Na) = 23, Magnesium (Mg = 24, Silicon (Si) = 28, Sulfur (S) = 32, Chlorine (Cl) = 35.5, Lead (Pb) = 207

**Molar Volume:** 22,4000 $cm^3$ at STP (273.15 K and 1 atm)

**Avodagdro's Number:** $6.02 \times 10^{23}$

1. Titanium has five common isotopes: $^{46}Ti$ (8.0%), $^{47}Ti$ (7.8%), $^{48}Ti$ (73.4%), $^{49}Ti$ (5.5%), $^{50}Ti$ (5.3%). What is the average atomic mass of titanium?

*Answer:*

Average Atomic Mass = (8/100 x 46) + (7.8/100 x 47) + (73.4/100 x 48) + (5.5/100 x 49) + (5.3/100 x 50)
= 3.68 + 3.67 + 35.23 + 2.695 + 2.65
= 47.93

2. A compound of Na, S and O contains 17.04% Na, 47.41% S. The $M_r$ of the compound is 270. Calculate the empirical formula, and then the molecular formula.

*Answer:*

| | Sodium | Sulfur | Oxygen |
|---|---|---|---|
| % composition | 17.04 | 47.41 | 35.25 |
| Ar | 23 | 32 | 16 |
| % composition/Ar | 17.04/23 = 0.74 | 47.41/32 = 1.48 | 35.25/16 = 2.2 |
| Ratio | 1 | 2 | 3 |

Empirical Formula: $NaS_2O_3$

3. In the sixteenth century, a large deposit of graphite was discovered in the Lake District. People at the time thought that the graphite was a form of lead. Nowadays, graphite is used in pencils but it is still referred to as 'pencil lead'. A student decided to investigate the number of carbon atoms in a 'pencil lead'. He found that the mass of the 'pencil lead' was 0.321 g.

a) Calculate the amount, in moles, of carbon atoms in the student's pencil lead. Assume that the 'pencil lead' is pure graphite.

*Answer:*

$A_r$ [C] = 12

Number of moles in 0.321 g of C = mass/$M_r$ = 0.321/12 = **0.02675**

b) Using the Avogadro constant, calculate the number of carbon atoms in the student's 'pencil lead'.

*Answer*

Number of carbon atoms in 0.02675 moles = 0.02675 x 6.02 x $10^{23}$ = **1.61 x $10^{22}$**

4. Calculate the concentration, in M, of the solution formed when 19.6 g of hydrogen chloride, HCl, are dissolved in water and the volume made up to 250 $cm^3$.

*Answer*

$M_r$ [HCl] = 36.5
Number of moles HCl in 19.6 g = mass/$M_r$ = 19.6/36.5 = 0.537
Number of moles HCl in 250 $cm^3$ = 0.537
Convert volume to litres ($dm^3$): 250cm3 = 0.25 litres
Concentration of HCl = number of moles/volume = 0.536/0.25 = **2.15 M**

5. Calculate the mass of $H_2O$ required to react completely with 5.0 g of $SiCl_4$:

$$SiCl_{4(l)} + 2H_2O_{(l)} \rightarrow SiO_{2(s)} + 4HCl_{(l)}$$

*Answer*

| | $SiCl_4$ | + | $2H_2O$ | $\rightarrow$ | $SiO_2$ | + | $4HCl$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 170 | | 18 | | 60 | | 36.5 |
| Mass Balance | 170 | | 36 | | 60 | | 146 |
| | | 206 | | | | 206 | |
| Reaction Coefficients | 1 | | 2 | | 1 | | 4 |
| Mass | 5 | | | | | | |
| No. of moles | 5/170 = 0.0294 | | 2 x 0.0294 = 0.0588 | | | | |

$M_r$ [$SiCl_4$] = 170
$M_r$ [$H_2O$] = 18
Number of moles $SiCl_4$ in 5 g = mass/$M_r$ = 5/170 = 0.0294
According to reaction coefficients, 1 mole of $SiCl_4$ reacts with 2 moles $H_2O$
Thus 0.0294 moles $SiCl_4$ will react with 2 x 0.0294 = 0.0588 moles $H_2O$
Mass of $H_2O$ = number of moles x $M_r$ = 0.0588 x 18 = **1.05g**

6. The equation for the reaction between magnesium carbonate and hydrochloric acid is given below.

$$MgCO_3 + 2HCl \rightarrow MgCl_2 + H_2O + CO_2$$

When 75.0 $cm^3$ of 0.500 M hydrochloric acid were added to 1.25 g of impure $MgCO_3$ some acid was left unreacted. This unreacted acid required 21.6 $cm^3$ of a 0.500 M solution of sodium hydroxide for complete reaction.

a) Calculate the number of moles of HCl in 75.0 $cm^3$ of 0.500 M hydrochloric acid.

*Answer*
Number of moles HCl in 75.0 $cm^3$ of 0.500 M = volume x concentration = 75/1000 x 0.500 = **0.0375**

b) Calculate the number of moles of NaOH used to neutralise the unreacted HCl.

*Answer*
Number of moles of NaOH in 21.6 $cm^3$ of a 0.500 M solution = volume x concentration = 21.6/1000 x 0.5 = **0.0108 M**

c) Show that the number of moles of HCl which reacted with the $MgCO_3$ in the sample was 0.0267.

*Answer*
Number of moles reacted with $MgCO_3$ = 0.0375 – 0.0108 = **0.0267**

d) Calculate the number of moles and the mass of $MgCO_3$ in the sample, and hence deduce the percentage by mass of in the sample.

*Answer*
$M_r$ [$MgCO_3$] = 84
According to the reaction coefficients, the number of moles of $M_2CO_3$ = 0.5 x number of moles of HCl
Thus number of moles of $MgCO_3$ = 0.5 x 0.0267 = 0.01335
Mass of 0.01355 moles of $MgCO_3$ = number of moles x $M_r$ = 0.01335 x 84 =1.12 g
% $MgCO_3$ in sample = 1.12/1.25 x 100 = **90%**

7. Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_{9\,(l)} \rightarrow 12CO_{2(g)} + 10H_2O_{(g)} + 6N_{2(g)} + O_{2(g)}$$

A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas

a) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

*Answer*

| | $4C_3H_5N_3O_{9(l)}$ | → | $12CO_{2(g)}$ | + | $10H_2O_{(l)}$ | + | $6N_{2(g)}$ | + | $O_{2(g)}$ |
|---|---|---|---|---|---|---|---|---|---|
| $M_r$ | 227 | | 44 | | 18 | | 28 | | 32 |
| Mass Balance | 908 | | 528 | | 180 | | 168 | | 32 |
| | | 908 | | | | | | 908 | |
| Reaction Coefficients | 4 | | 12 | | 10 | | 6 | | 1 |
| Mass | 0.44 x 227 = 9.988 | | | | | | | | 0.35 |
| No. of moles | 4 x 1.1 x $10^{-3}$ = 0.044 | | | | | | | | 0.35/16 = 1.09 x $10^{-3}$ |

$M_r[O_2]$= 32 g $mol^{-1}$
Number of moles in 0.350 g $O_2$ = mass/$M_r$ = 0.350/32 = **0.011**

Total number of moles of gas produced = 29 x 0.011 = 0.319

b) Calculate the number of moles, and the mass, of nitroglycerine detonated.

*Answer*

$M_r$ [$C_3H_5N_3O_9$] = 227

According to reaction coefficients, 4 moles nitroglycerine produce 1 mole $O_2$

Therefore 0.011 moles $O_2$ are generated from 4 x 0.011 = 0.044 mole nitroglycerine

Mass of 0.044 moles nitroglycerine = number of moles x $M_r$ = 0.044 x 227 = **9.988 g**

8. What mass of lead(II) sulfate would be produced by the action of excess dilute sulphuric acid on 10 g of lead nitrate dissolved in water?

$Pb(NO_3)_{2(aq)} + H_2SO_{4(aq)} \rightarrow PbSO_{4(s)} + 2HNO_{3(aq)}$

*Answer:*

| | $Pb(NO_3)_{2(aq)}$ | + | $H_2SO_{4(aq)}$ | → | $PbSO_{4(aq)}$ | + | $2HNO_{3(aq)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 331 | | 98 | | 303 | | 63 |
| Mass Balance | | | | | 303 | | 126 |
| | | 429 | | | | 429 | |
| Reaction Coefficients | 1 | | 1 | | 1 | | 1 |
| Mass | 10 | | | | 9.15 | | |
| No. of moles | 0.0302 | | | | 0.0302 | | |
| Reaction coefficients | | | | | | | |

Mr [$Pb(NO_3)_2$ = 331

Number of moles of $Pb(NO_3)_2$ moles in 10g = 10/331 = 0.0302

According to the reaction coefficients I mole of $Pb(NO_3)$2 produces 1 mole of $PbSO_4$

Therefore, number of moles of $PbSO_4$ generated from 10g of Pb(NO3)2 = 0.0302 moles

Mass of 0.0302 moles $PbSO_4$ = 0.0304 x 303 = **9.15g**

9. Ammonium sulfate reacts with aqueous sodium hydroxide as shown by the equation below.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

A sample of ammonium sulfate was heated with 100 $cm^3$ of 0.500 M aqueous sodium hydroxide. To ensure that all the ammonium sulfate reacted, an excess of sodium hydroxide was used. Heating was continued until all of the ammonia had been driven off as a gas. The unreacted sodium hydroxide remaining in the solution required 27.3 $cm^3$ of 0.600 M hydrochloric acid for neutralisation.

*Answer*

| | $(NH_4)_2SO_{4(s)}$ | + | $2NaOH_{(aq)}$ | → | $2NH_{3(aq)}$ | + | $Na_2SO_{4(aq)}$ | + | $2H_2O_{(l)}$ |
|---|---|---|---|---|---|---|---|---|---|
| $M_r$ | 132 | | 40 | | 17 | | 142 | | 18 |
| Mass Balance | 132 | | 80 | | 34 | | 142 | | 36 |
| | | 212 | | | | | | 212 | |
| Reaction Coefficients | 1 | | 2 | | 2 | | 1 | | 1 |

| | | |
|---|---|---|
| Mass | 0.0168 x 132 = 2.22 | |
| No. of moles | 0.0336 x 0.5 = 0.0168 | 0.0366 |
| Volume ($cm^3$) | | |
| Concentration | | |

a) Calculate the original number of moles of NaOH in 100 $cm^3$ of 0.500 M aqueous sodium hydroxide.

*Answer*

Number of moles of NaOH in 100 $cm^3$ of 0.500 M = volume x concentration = 100/1000 x 0.500 = **0.05 moles**

b) Calculate the number of moles of HCl in 27.3 $cm^3$ of 0.600 M hydrochloric acid.

*Answer*

Number of moles of HCl in 27.3 $cm^3$ of 0.600 M = volume x concentration = 27.3/1000 x 0.600 = **0.0164**

c) Deduce the number of moles of the unreacted NaOH neutralised by the hydrochloric acid.

*Answer*

According to the reaction coefficients 1 mole of HCl neutralizes 1 mole of NaOH

The number of mole of unreacted NaOH = **0.164**

d) Calculate the number of moles of NaOH which reacted with the ammonium sulfate

*Answer*

Number of moles of NaOH reacted with ammonium sulfate = 0.05 – 0.0164 = **0.0336**

e) Calculate the number of moles and the mass of ammonium sulfate in the sample.

*Answer*

$M_r$ [$(NH_4)_2SO_4$] = 132

According to the balanced chemical equation two (2) moles of NaOH react with every mole of $(NH_4)_2SO_4$

Therefore, 0.0336 moles of NaOH react with 0.5 x 0.336 = 0.0168 moles $(NH_4)_2SO_4$

Mass of 0.0168 moles of $(NH_4)_2SO_4$ = number of moles x $M_r$ = 0.0168 x 132 = **2.22 g**

10. A sample of sodium hydrogencarbonate was tested for purity using the following method. 0.400g of the solid was dissolved in 100.0 $cm^3$ of water and titrated with 0.200 M hydrochloric acid using methyl orange indicator.

$$NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(s)} + CO_{2\,(g)} + H_{2(g)}$$

23.75 $cm^3$ of acid was required for complete neutralisation. [Ar's: Na = 23, H = 1, C = 12, O = 16]

a) Calculate the moles of acid used in the titration and the moles of sodium hydrogencarbonate titrated.

*Answer*

Number of moles of HCl = 23.75/1000 x 0.2 = 4.75 x $10^{-3}$ moles

b) Determine the mass of sodium hydrogen carbonate titrated and hence the purity of the sample.

*Answer:*

| | $NaHCO_{3(s)}$ | + $HCl_{(aq)}$ | → $NaCl + CO_2 + H_2$ |
|---|---|---|---|
| Volume ($cm^3$) | 100 | 23.75 | |
| No. of moles | 4.75 x $10^{-3}$ | 23.75/1000 x 0.2 = 4.75 x $10^{-3}$ | |
| Concentration (M) | 1000/100 x 4.75 x $10^{-3}$ = 0.0475 | 0.2 | |
| Mass | 0.0475 x 84 = 3.99g | | |

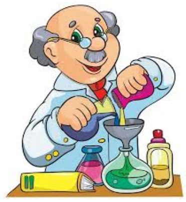
$M_r[NaHCO_3]$ = 84

Mass of 0.0475 moles $NaHCO_3$ = 0.0475 x 84 = 3.99g

% purity = 3.99/4.00 x 100 = **99.75%**

# Moles Test

## No.3



To Pass the Moles Test you will need to achieve a score of greater than 70%. Each question is equally weighted (5%).

**Relative Atomic Masses:**
Hydrogen (H) = 1, Carbon (C) = 12, Nitrogen (N) = 14, Oxygen (O) = 16, Sodium (Na) = 23, Magnesium (Mg = 24, Silicon (Si) = 28, Sulfur (S) = 32, Chlorine (Cl) = 35.5, Potassium (K) = 39, Titanium (Ti) = 48, Barium (Ba) = 137

**Molar Volume:** 22,4000 $cm^3$ at STP (273.15 K and 1 atm)

**Avodagdro's Number:** $6.02 \times 10^{23}$ $mol^{-1}$

1. One isotope of sodium has a relative mass of 23.

Calculate the mass, in grams, of a single atom of this isotope of sodium.

*Answer*
Mass of $6.02 \times 10^{23}$ atoms of sodium = 23 g
Mass of one atom of Na = $23/6.02 \times 10^{23} = 3.82 \times 10^{-23}$

2. A compound contains 12.8% carbon and 2.13% Hydrogen, the rest being Bromine. The relative molecular mass of the compound is 188. Calculate the empirical formula and the molecular formula of the compound.

*Answer:*

| | Carbon | Hydrogen | Bromine |
|---|---|---|---|
| % composition | 12.8 | 2.13 | 85.07 |
| Ar | 12 | 1 | 80 |
| % composition/Ar | 12.8/12 = 1.06 | 2.13/1 = 2.13 | 85.07/80 =1.06 |
| Ratio | 1 | 2 | 1 |

Empirical Formula: $CH_2Br$
Mr [$CH_2Br$] = 94
n = 188/94 = 2
Molecular Formula = $(CH_2Br)n$ = $C_2H_4Br_2$

3. Calculate the mass of phosphorus required to make 200 g of phosphine, $PH_3$, by the reaction:

$$P_{4(s)} + 3NaOH_{(aq)} + 3H_2O_{(l)} \rightarrow 3NaH_2PO_{4(aq)} + PH_{3(g)}$$

*Answer*

| | $P_{4(s)}$ | + | $3NaOH_{(aq)}$ | + | $3H_2O_{(l)}$ | → | $3NaH_2PO_{2(aq)}$ | + | $PH_{3(g)}$ |
|---|---|---|---|---|---|---|---|---|---|
| $M_r$ | 124 | | 40 | | 18 | | 88 | | 34 |
| Mass Balance | 124 | | 120 | | 54 | | 264 | | |
| | | | | 298 | | | | 298 | |
| Reaction Coefficients | 1 | | 3 | | 3 | | 3 | | 1 |
| Mass | 5.88 x 124 = **729** | | | | | | | | |
| No. of moles | 5.88 | | | | | | | | 200/34 = 5.88 |

$M_r$ [$PH_3$] = 34
$M_r$ [$P_4$] = 124
Number of moles in 200 g $PH_3$ = mass/$M_r$ = 200/34 = 5.88
According to the reaction coefficients, 1 mole of $PH_3$ is produced from 1 mole $P_4$
Therefore 5.88 moles $P_4$ are required to produced 5.88 moles $PH_3$
Mass of 5.88 moles $P_4$ = number of moles x $M_r$ = 5.88 x 124 = **729.**

4. A student heats 5.29g of $Sr(NO_3)_2$ and collects the gas.

$$2Sr(NO_3)_{2(s)} \rightarrow 2SrO(s) + 4NO_{2(g)} + O_{2(g)}$$

Calculate the volume of gas, in $dm^3$, obtained by the student at STP. Molar mass of $Sr(NO_3)_2$ = 211.6 g $mol^{-1}$.

*Answer*

| | $2Sr(NO_3)_{2(s)}$ | → | $2SrO_{(s)}$ | + | $4NO_{2(g)}$ | + | $O_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 211.6 | | | | | | |
| Reaction Coefficients | 2 | | 2 | | 4 | | 1 |
| Mass | 5.29 | | | | | | |
| No. of moles | 5.29/211.6 = 0.025 | | | | 0.05 | | 0.0125 |

$M_r$ [$Sr(NO_3)_2$] = 211.6
Number of moles of $Sr(NO_3)_2$ in 5.29 g = 5.29/211.6 = 0.025
According to the balanced chemical reaction one mole of $Sr(NO_3)_2$ generates 2.5 moles of gas
Thus 0.025 moles $Sr(NO_3)_2$ will generate 2.5 x 0.025 = 0.0625 moles of gas
One mole of a gas at STP occupies a volume of 22400 $cm^3$
Therefore 0.0625 moles will occupy a volume of 0.0625 x 22400 = **1400 $cm^3$**

5. A student heats 12.41g of hydrated sodium thiosulfate, $Na_2S_2O_3 \cdot 5H_2O$, to remove the water of crystallisation. A white powder called anhydrous sodium thiosulfate forms.

a) What is the relative formula mass of $Na_2S_2O_3 \cdot 5H_2O$?

*Answer*

$M_r$ [$Na_2S_2O_3$•$5H_2O$] = (23 x2) + (32 x 2)+ (16 x 3) + (5 x 18) = 46 + 64+ 48 + 90 = **248**

b) Calculate the expected mass of anhydrous sodium thiosulfate that forms.

*Answer*

$M_r$ [$Na_2S_2O_3$•$5H_2O$] = 248

$M_r$ [$Na_2S_2O_3$] = 158

Number of moles in 12.41 g $Na_2S_2O_3$•$5H_2O$ = mass/$M_r$ = 12.41/248 = 0.05

Number of moles of anhydrous $Na_2S_2O_3$ = 0.05

Mass of 0.05 moles $Na_2S_2O_3$ = 0.05 x 158 = 7.9 g

6. The metal titanium is obtained by the Kroll process in which titanium ore is converted into titanium chloride and then reduced using magnesium in an atmosphere of argon.

$$2Mg + TiCl_4 \rightarrow 2MgCl_2 + Ti$$

In industry 3800 kg of titanium chloride are added to 1500 kg of magnesium. Calculate the maximum mass of titanium produced in this reaction.

*Answer*

| | $2Mg_{(aq)}$ | + | $TiCl_{4(l)}$ | → | $2MgCl_{2(aq)}$ | + | $Ti_{(aq)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 24 | | 190 | | 95 | | 48 |
| Mass Balance | 48 | 138 | 190 | | 190 | 138 | |
| Reaction Coefficients | 2 | | 1 | | 2 | | 1 |
| Mass (g) | 150000 | | 380000 | | | | 20,000 x 48 = 960000 |
| No. of moles | 1500000/48 = 62,500 | | 380000/190 = 20,000 | | | | 20,000 |

$M_r$ [$TiCl_4$] = 190

Number of moles of TiCl4 in 3800 kg (380000 g) = 380000/190 = 20,000

According to the balanced chemical equation, one mole of $TiCl_4$ can generate one mole Ti

Therefore 20,000 moles of $TiCl_4$ can generate 20,000 moles Ti

Mass of 20,000 moles of Ti = 20,000 x 48 = 960,000 g = **960 kg**

7. In the exhaust stroke the gaseous products escape. Calculate the volume of carbon dioxide produced, at STP, if 1 mg of octane, $C_8H_{18}$, is completely combusted.

a) Calculate the number of moles of octane in 1 mg.

*Answer*

| | $C_8H_{18}$ | + | $12.5O_2$ | → | $8CO_2$ | + | $9H_2O$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 114 | | 32 | | 44 | | 18 |
| Mass Balance | 114 | 514 | 400 | | 352 | 514 | 162 |
| Reaction Coefficients | 1 | | 12.5 | | 8 | | 9 |
| Mass | $1 \times 10^{-3}$ | | | | | | |

| | | |
|---|---|---|
| No. of moles | 0.001/114 = **8.77 x $10^{-6}$** | 8 x 8.77 x $10^{-6}$ = 7.018 x $10^{-5}$ |
| Volume ($cm^3$) | | 7.018 x $10^{-5}$ x 22400 = 1.57 |

$M_r [C_8H_{18}]$ = 114
1 mg = 0.001 g
Number of moles of $C_8H_{18}$ in 0.001 g = mass / $M_r$ = 0.001/114 = **8.77 x $10^{-6}$ g**

b) Calculate the number of moles and hence the of carbon dioxide produced.

*Answer*
One mole of $C_8H_{18}$ will produce 8 moles of $CO_2$ on complete combustion
Therefore, the number of mole of $CO_2$ produced = 8 x 8.77 x $10^{-6}$ = **7.018 x $10^{-5}$**
One mole of a gas occupies a volume of 22400 $cm^3$
Therefore, 5.26 x $10^{-5}$ moles of $CO_2$ will occupy a volume of 7.018 x $10^{-5}$ x 22400 = **1.57 $cm^3$**

8. The carbonate of metal **M** has the formula $M_2CO_3$. The equation for the reaction of this carbonate with hydrochloric acid is given below.

$$M_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2MCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

A sample of $M_2CO_3$ of mass 0.394 g, required the addition of 21.7 $cm^3$ of a 0.263 M solution of hydrochloric acid for complete reaction.

a) Calculate the number of moles of hydrochloric acid used.

*Answer*

| | $M_2CO_{3(s)}$ | + | $2HCl_{(aq)}$ | $\rightarrow$ | $2MCl_{(aq)}$ | + | $CO_{2(g)}$ | + | $H_2O_{(l)}$ |
|---|---|---|---|---|---|---|---|---|---|
| $M_r$ | | | | | | | | | |
| Mass Balance | | | | | | | | | |
| Reaction Coefficients | 1 | | 2 | | 2 | | 1 | | 1 |
| Mass | 0.394 | | | | | | | | |
| No. of moles | | | 21.7/1000 x 0.263 = 5.7 x$10^{-3}$ | | | | | | |
| Concentration (M) | | | 0.263 | | | | | | |
| Volume | | | 21.7 | | | | | | |

Number of moles HCl in of 21.7 $cm^3$ of a 0.263 M solution of hydrochloric acid = volume x concentration = 21.7/1000 x 0.263 = **5.7 x$10^{-3}$**

b) Deduce the relative molecular mass of $M_2CO_3$ and hence the identity of M

*Answer*
According to the reaction coefficients 1 mole of $M_2CO_3$ reacts with 2 moles HCl
Therefore, the number of moles $M_2CO_3$ in 0.394 g = 0.5 x number of moles of HCl = 0.5 x 5.7 x$10^{-3}$ = **2.85 x $10^{-3}$**
Given that 2.85 x $10^{-3}$ moles $M_2CO_3$ has a mass of 0.394 g, then one mole (ie Mr) will have a mass of 1/2.85 x $10^{-3}$ x 0.394 = **138 g $mol^{-1}$**

$M_r[CO_3]$= 60
Therefore 2 x $A_r$ [M] = 138 – 60 = 78
$A_r$ [M] = 78/2 = 39
Thus M = **potassium (K)**

9. A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_{3(aq)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$$

In a titration, 25.0 $cm^3$ of a 1.24 M solution of sulfuric acid required 30.8 $cm^3$ of this ammonia solution for complete reaction.

Calculate the concentration of ammonia in this solution and the mass of ammonium sulphate in the solution at the end of this titration.

*Answer*
Number of moles of $H_2SO_4$ in 25 $cm^3$ of 1.24 M = volume x concentration = 25/100 x 1.24 = 0.031
At the end point, number of moles of $NH_3$= 2 x number of moles of $H_2SO_4$ = 0.062
Thus the number of moles $NH_3$ in 30.8 $cm^3$ = 0.062
Therefore, concentration of $NH_3$ = number of moles in 1000 $cm^3$ = 1000/30.8 x 0.062 = **2.01 M**

10. Hydrogen can be made by the reaction of hydrochloric acid with magnesium according to the equation:

$$2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_2 + H_2$$

What mass of hydrogen is formed when 100 $cm^3$ of hydrochloric acid of concentration 5.0 M reacts with an excess of magnesium?

*Answer*

| | $2HCl_{(aq)}$ | + | $Mg_{(s)}$ | → | $MgCl_{2(aq)}$ | + | $H_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 36.5 | | 24 | | 95 | | 2 |
| Mass Balance | 73 | | 24 | | | | |
| | | 97 | | | | 97 | |
| Reaction Coefficients | 2 | | 1 | | 1 | | 1 |
| Mass | | | | | | | 0.25 x 2 = **0.5** |
| No. of moles | 100/1000 x 5 = 0.5 | | | | | | 0.5/2 = 0.25 |

$M_r$ [$H_2$] = 2 g $mol^{-1}$
Number of moles of HCl in 100 $cm^3$ solution of 5 M concentration = 100/1000 x 5 = 0.5 moles
According to the balanced chemical reaction, number of moles of $H_2$ = 0.5 x number of moles of HCl
Therefore, the maximum number of moles of $H_2$ generated from 0.5 moles of HCl = 0.5 x 0.5 = 0.25
Mass of 0.25 $H_2$ = 0.25 x 2 = **0.5 g**

11. Ammonium nitrate can be prepared by the reaction between ammonia and nitric acid:

$$NH_{3(aq)} + HNO_{3(aq)} \rightarrow NH_4NO_{3\,(aq)}$$

The concentration of a nitric acid solution is 2.00 M. Calculate the volume of this solution, which would be required to react with exactly 20.0 g of ammonia.

*Answer*

| | $NH_{3(aq)}$ | + | $HNO_{3(aq)}$ | → | $NH_4NO_{3(aq)}$ |
|---|---|---|---|---|---|
| $M_r$ | 17 | | 63 | | 80 |
| Mass Balance | | 80 | | | 80 |
| Reaction Coefficients | 1 | | 1 | | 1 |
| Mass | 20 | | | | |
| No. of moles | 20/17 = 1.18 | | 1.18 | | 1.18 |
| Volume ($cm^3$) | | | 1000/2 x 1.18 = 590 | | |

$M_r$ [$NH_3$] = 17
Number of moles in 20 g $NH_3$ = 20/17 = 1.18
According to the balanced chemical equation, one mole of $NH_3$ reacts with one mole of $HNO_3$
Therefore number of moles of $HNO_3$ to react with 1.18 mole of $NH_3$ = 1.18
Volume of 2.00 M $HNO_3$ that contains 1.18 moles = 1000/2 x 1.18 = **590 $cm^3$**

12. The equation below represents the thermal decomposition of $KClO_3$.

$$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$$

a ) Calculate the mass of oxygen which could be produced by the complete decomposition of 1.47 g of $KClO_3$.

*Answer*

| | $2KClO_{3(s)}$ | → | $2KCl_{(s)}$ | + | $3O_{2(g)}$ |
|---|---|---|---|---|---|
| $M_r$ | 122.5 | | 74.5 | | 32 |
| Mass Balance | 2 x 122.5<br>245 | | 149 | 245 | 96 |
| Reaction Coefficients | 2 | | 1 | | 1 |
| Mass | 1.47 | | | | 0.018 x 32 = **0.576** |
| No. of moles | 1.47/122.5 = 0.012 | | 0.012 | | 1.5 x 0.12 = 0.018 |

$M_r$ [$KClO_3$] = 122.5
$M_r$ [$O_2$] = 32
Number of moles of $KClO_3$ in 1.47 g = 1.47/122.5 = 0.012
According to the balanced chemical equation, one mole $KClO_3$ produces 1.5 moles of $O_2$
Therefore 0.012 moles of $KClO_3$ could generate 1.5 x 0.12 = 0.018 moles of $O_2$
Mass of 0.018 moles of $O_2$ = 0.018 x 32 = **0.576 g**

b) Calculate the mass of $KClO_3$ required to produce 1.00 $dm^3$ (at STP) of oxygen.

*Answer*

Number of moles of $O_2$ in 1L (1000$cm_3$) of $O_2$ at STP (1 L) = volume/$V_m$ = 1000/22400 = 0.0446
According to the balanced chemical equation 0.67 (ie 2/3) moles of $KClO_3$ are required to produce one mole of $O_2$
Therefore the number of moles of $KClO_3$ to produce 0.0446 moles $O_2$ = 0.047 x 0.67 = 0.03 moles
Mass of 0.03 moles $KClO_3$ = number of moles x $M_r$ = 0.03 x 122.5 = **3.66 g**

13. A solution of sodium hydroxide contained 0.250 M. Using phenolphthalein indicator, titration of 25.0 $cm^3$ of this solution required 22.5 $cm^3$ of a hydrochloric acid solution for complete neutralisation. Determine the molarity of the HCl

*Answers*

| | $NaOH_{(aq)}$ | + | $HCl_{(aq)}$ | → | $NaCl_{(aq)} + H_2O_{(l)}$ |
|---|---|---|---|---|---|
| Volume ($cm^3$) | 25 | | 22.5 | | |
| No. of moles | 25/1000 x 0.25 = $6.25 \times 10^{-3}$ | | $6.25 \times 10^{-3}$ | | |
| Concentration (M) | 0.25 | | 1000/22.5 x 6.25 x $10^{-3}$ = **0.278** | | |

Number of moles of NaOH in 25 $cm^3$ of 0.25M = 25/1000 x 0.25 = 625 x $10^{-3}$
At the end point, the number of moles of NaOH = number of moles of HCl
Therefore, the number of moles of HCl in 22.5 $cm^3$ = 6.25 x $10^{-3}$
Concentration of HCl = 1000/22.5 x 6.25 x $10^{-3}$ = **0.278M**

14. When barium nitrate is heated it decomposes as follows:

$$Ba(NO_3)_{2(s)} \rightarrow BaO_{(s)} + 2NO_{2(g)} + ½\ O_{2(g)}$$

a) Calculate the total volume, measured at STP, of gas, which is produced by decomposing 5.00 g of barium nitrate.

*Answer*

| | $Ba(NO_3)_{2(s)}$ | → | $BaO_{(s)}$ | + | $2NO_{2(g)}$ | + | ½ $O_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| $M_r$ | 261 | | 153 | | 46 | | 16 |
| Mass Balance | 261 | | | | 92 | | |
| | | | | | | 261 | |
| Reaction Coefficients | 1 | | 1 | | 2 | | 0.5 |
| Mass | 5 | | | | | | |
| No. of moles | 5/261 = 0.01915 | | | | 0.01915 x 2 = 0.038 | | 0.01915 x 0.5 = 0.0096 |

$M_r$ [$Ba(NO_3)_2$] = 261
Number of moles in 5g of $Ba(NO_3)_2$ = mass/$M_r$ = 5/261 = 0.01915
According to the reaction coefficients, 1 mole of $Ba(NO_3)_2$ generates 2.5 moles of gas
Thus, 0.01915 moles of $Ba(NO_3)_2$ will generate 2.5 x 0.01915 = 0.048 moles of gas
Volume occupied at STP by 0.048 moles of gas = number of moles x $V_m$ = 0.048 x 22400 = **1073 $cm^3$**

b) Calculate the volume of 1.20 M hydrochloric acid which is required to neutralise exactly the barium oxide formed by decomposition of 5.00 g of calcium nitrate. Calcium oxide reacts with hydrochloric acid as follows:

$$CaO_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)}$$

*Answer*

| | $CaO_{(s)}$ | + | $2HCl_{(aq)}$ | → | $CaCl_{2(aq)}$ | + | $H_2O_{(l)}$ |
|---|---|---|---|---|---|---|---|

| | | |
|---|---|---|
| Volume ($cm^3$) | | 1000/1.2 x 0.0383 = **31.9** |
| No. of moles | 0.01915 | 2 x 0.01915 = 0.0383 |
| Concentration (M) | | 1.21 |

According to the reaction coefficients 1 mole of $Ba(NO_3)_2$ produces 1 mole of BaO
Thus, 0.01915 moles $Ba(NO_3)_2$ will produce 0.01915 moles of BaO
1 mole of BaO requires 2 moles of HCl to be neutralised
Therefore 2 x 0.01915 = 0.0383 moles of HCl are required to neutralize the BaO
Volume of 1.2 M required = 1000/1.2 x 0.0383 = **31.9 $cm^3$**

15. 1.133 g of silver nitrate was heated in an open tube. The silver residue weighed 0.720 g. During the reaction 0.307 g of nitrogen dioxide was also produced. The rest of the mass loss was due to oxygen. Use the data to write the equation for the reaction.

*Answer:*

| | $AgNO_{3\,(s)}$ | → | $Ag_{(s)}$ | + | $NO_{2(g)}$ | + | $O_{2(g)}$ |
|---|---|---|---|---|---|---|---|
| Mass | 1.133 | | 0.72 | | 0.307 | | 0.106 |
| No. of moles | 0.0067 | | 0.0067 | | 0.0067 | | 0.0033 |
| Reaction Coefficients | 2 | | 2 | | 1 | | 1 |

Mass of oxygen released = 1.133 – 0.72 – 0.307 g = 0.106 g
Number of moles of $AgNO_3$ in 1.133 g = mass/$M_r$ = 1.133/170 = 0.0067
Number of moles of Ag in 0.72 g = mass/$M_r$ = 0.72/108 = 0.0067
Number of moles of $NO_2$ in 0.307 g = mass/$M_r$ = 0.307/46 = 0.0067
Thus 0.0067 moles of $AgNO_3$ thermally decompose to produce 0.0067 moles Ag + 0.0067 moles $NO_2$ + 0.0033 moles $O_2$
Thus, 2 moles of $AgNO_3$ thermally degrade to produce 2 moles of Ag + 2 moles of $NO_2$ + 1 mole $O_2$

**$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$**