Chemistry answers section 2

Activity 2.1.1:

1. C:O = 3:8 Therefore Mass of O = mass of C x 8/3 = 6 x 8/3 = 16 g
2. H is 1/9 of the total mass: 1/9 x 36 g = 4 g and O is 8/9 of the total mass: 8/9 x 36 = 32 g.

Activity 2.1.2:

1. Mass product = mass A + mass B = 300g + 100g = 400 g
2. Mass B = Mass AB – Mass A = 25g – 10g = 15 g
3. Mass NaCl = Mass $CaCl_2$ + Mass Na_2CO_3 - Mass $CaCO_3$ = 2.12g + 2.20g – 2.90g = 1.42 g
4. Mass calcium oxide = Mass calcium + Mass oxygen = 40.0g + 16.0g = 56.0 g
5. Mass oxygen used up = Mass magnesium oxide - Mass magnesium = 40.0g – 24.0g = 16.0 g

Activity 2.1.3:

1. Methane gas reacts with oxygen to form carbon dioxide gas and water vapour.
   For balancing:
   a. $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
      LHS: 1C, 4H, 2O RHS: 1C, 2H, 3O
   b. $CH_4 (g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
      LHS: 1C, 4H, 4O RHS: 1C, 4H, 4O

   The equation is balanced: $CH_4 (g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

2. Silver nitrate reacts with aqueous sodium chloride to form solid silver chloride and aqueous sodium nitrate
   For balancing:
   a. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
      LHS: 1Ag, 1NO_3^-, 1Na, 1Cl RHS: 1Ag, 1NO_3^-, 1Na, 1Cl

The equation is balanced.

3. Solid sodium reacts with water to form aqueous sodium hydroxide and hydrogen gas.

   For balancing:

   a. $Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$
      LHS: 1Na, 2H, 1O RHS: 1Na, 1OH, 2H
   b. $Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
      LHS: 1Na, 4H, 2O RHS: 2Na, 4H, 2O
   c. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
      LHS: 2Na, 4H, 2O RHS: 2Na, 4H, 2O

   The equation is balanced:

   $$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

4. Ammonia gas breaks down (decomposes) to form nitrogen gas and hydrogen gas.

   For balancing

   a. $NH_3(g) \rightarrow N_2(g) + H_2(g)$
      LHS: 1N, 3H, RHS: 2N, 2H
   b. $2NH_3(g) \rightarrow N_2(g) + H_2(g)$
      LHS: 2N, 6H RHS: 2N, 2H
   c. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$
      LHS: 2N, 6H RHS: 2N, 6H

   The equation is balanced: $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

5. Sodium bicarbonate solid decomposes to form sodium carbonate, carbon dioxide gas and water vapour.

   a. $NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$
      LHS: 1Na, 1H, 1C and 3O RHS: 2Na, 2C, 6O, 2H
   b. $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$

LHS: 2Na, 2H, 2C and 6O   RHS: 2Na, 2C, 6O, 2H

The equation is balanced:

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

Activity 2.2 1

Product	**Mass of 12 units (g)**	**Average mass of 1 unit (g)**	**Mass of the bag of product (g)**	**Number of units per bag**	**Number of units in a 1000 g bag of product**
e.g. Rice	(e.g. 12 grains of rice)	(e.g. 1 grain of rice)	(e.g. mass of whole bag of rice)	(e.g. number of grains of rice in the bag)	(e.g. number of grains of rice in a bag weighing 1000 g)
Rice	0.0125 x 12 = 0.15	0.15/12 = 0.0125	1000	1 x 1000.00/0.0125 = 80 000	80 000
Sugar	0.0017 x 12 = 0.02	0.02/12 = 0.0017	500	1 x 500/0.0017 =2941117.65 = 2941117 (whole units)	2941117 x 1000/500 = 5882234
Apples	118.15 x 12 = 1417.80	1417.80/12 = 118.15	1500	1 x 1500/118.15 = 12.69 = 13 (must be whole apples!)	13 x 1000/1500 = 8.67 = 9 (whole number)
Dried beans	0.97 x 12 = 11.64	11.64/12 = 0.97	500	1 x 500.00/0.97 = 515.46 = 515 (whole units)	515 x 1000/500 = 1030
Eggs	61.28 x 12 = 735.36	735.36/12 = 61.28	750	1 x 750/61.28 = 12.24 = 12 (whole number)	12 x 1000/750 = 16

1. A dozen.
2. Work out (by calculation, not by weighing), the average mass of a single unit of each product e.g. a single grain of rice, and add this information to your table.
3. Now calculate the number of units in each bag, and add this information to your table.
4. Now calculate the number of units in a 1000 g bag of each product and add the information to the table.
5.
    a. When a product is made up of very small units that would be difficult or tedious to count out e.g. rice and sugar, mass is an easier unit of measurement.
    b. Larger items are easy to handle and count.
    c. The lower the mass of an individual unit, the greater the number of units required to make up 1000 g. So sugar, with the smallest particles has the greatest number of units per 1000 g, and apples, which are the heaviest have the lowest number of units per 1000 g.
    d. To get the same number of items of different products different masses would need to be weighed.
    e. The same mass for each customer would supply the same number of units.
    f. 1 atom = 0.000 000 000 000 000 000 000 01 g (1×10^{-23} g)
       x no of atoms = 1.00 g
       $x = 1.00 \times 1/(1 \times 10^{-23}) = 1 \times 10^{23}$
       You must weigh 1×10^{23} atoms to get a mass of 1 g.
    g. Atoms are invisible to us therefore cannot be counted.

Activity 2.2.2: Relating atomic number and mass

a. The mass of a single atom of each element is equal to the atomic number on the Periodic Table for that element.
b. The mass in grams of 6.02×10^{23} atoms of a particular element is equal to the mass of one atom (amu) of that element.
c. The mass of 6.02×10^{23} atoms of a particular element is equal to the atomic mass number in grams.
d. The mass of 6.02×10^{23} atoms of a particular element becomes an easily measured amount (in grams) in the laboratory. So we

can relate mass (in grams) of a subsatnce to a particular number of atoms.

Activity 2.2.3: Mass, moles and Avogadro's Number

1. RAM Ca = 40.08 amu → mass of 1 mole = 40.08 g
2. Mass of 1 mole of nickel atoms = 58.69 g → Mass of 0.235 moles = 0.235 x 58.69 g = 13.79 g
3. 1 mole contains 6.02 x 10^{23} atoms → 0.250 moles contains 0.250 x 6.02 x 10^{23} atoms → 1.51 x 10^{23} atoms
4. 1 mole of arsenic contains 6.02 x 10^{23} arsenic atoms → 3.2 moles contains 3.2 x 6.02 x 10^{23} atoms = 19.26 x 10^{23} = 1.93 x 10^{24} atoms
5. 6.02 x 10^{23} atoms of aluminium have a mass of 26.98 g → 3.02 x 10^{23} atoms have a mass = (3.02 x 10^{23}/6.02 x 10^{23}) x 26.98 g = 13.54 g
6. 6.02 x 10^{23} atoms of caesium have a mass of 132.9 g → 10 000 atoms have a mass = (1.0 x 10^{4}/6.02 x 10^{23}) x 132.9 g = 1.7 x 10^{-20}

Activity 2.2.4:

The molar mass of the compound would be the sum of the molar masses of the constituent elements of the compound.

CO_2 would have a molar mass = 12.01 + (2 x 16.00) = 44.01 g

Mass of C = 12.01 g; Mass of O = 32.00 g

NaOH would have a molar mass = 22.99 + 16.00 + 1.01 = 40.00 g

Mass of Na = 22.99 g; Mass of O = 16.00 g; Mass of H = 1.01 g

H_2SO_4 would have a molar mass = (2 x 1.01) + 32.06 + (4 x 16.00)

= 98.08 g

Mass of H = 2.01 g; Mass of S = 32.06 g; Mass of O = 64.00 g

Activity 2.2.5: Working with formula and molar masses

1. Answer the following questions and place your answers in a table like the one suggested below:

	CO	$AlCl_3$	H_2O	Fe_2O_3
Type structure	Molecule	Formula unit	Molecule	Formula unit
Molar mass (g)	12.01 + 16.00 = 28.01	26.98 + (3 x 35.45) = 133.33	(2 x 1.01) + 16.00 = 18.02	(2 x 55.85) + (3 x 16.00) = 159.70
Total atomic mass first element (g)	12.01	26.98	2.02	111.70
Atomic mass second element (g)	16.00	106.35	16.00	48.00
% first element	12.01/28.01 x 100% = 42.88%	26.98/133.33 x 100% = 20.24%	2.02/18.02 xx 100% = 11.21%	111.70/159.70 xx 100% = 69.94%
% second element	16.00/28.01 x 100% = 57.12%	106.35/133.33 x 100% = 79.76%	16.00/18.02 x 100% = 88.79%	48.00/159.70 x 100% = 30.06%
Total %	42.88% + 57.12% = 100%	20.24% + 79.76% = 100%	11.21% + 88.79% = 100%	69.94% + 30.06% = 100%
Mass first element per 100 g	42.88/100 x 100g = 42.88g	20.24/100 x 100g = 20.24g	11.21/100 x 100g = 11.21g	69.94/100 x 100g = 69.94g
Mass second element per 100 g	57.12/100 x 100g = 57.12g	79.76/100 x 100g = 79.76g	88.79/100 x 100g = 88.79g	30.06/100 x 100g = 30.06g

e.
f. The % (by mass) is the mass of each element present in any mass of the compound e.g. in CO, C forms 42.88% of the total mass and O forms 57.12% of the total mass.
g. The % will stay constant for a particular compound (Law of Constant composition) but it varies between different compounds.
h. The percentage composition (by mass) of elements in a compound is the ratio of all the elements present in the compound expressed as a percentage of their relative masses.
i.
j. A compound composed of 4 different elements would have 4 % composition values to describe its composition – one for each of the component elements.

Activity 2.2.6:

1. Molar mass CO_2 = 12.01 + (2 x 16.00) = 44.01
   % C in CO_2 = 12.01/44.01 x 100% = 27.29%
   Mass C in 150 g = 27.29/100 x 150.0 g = 40.94 g
2. Molar mass CO = 12.01 + 16.00 = 28.01
   % C in CO_2 = 12.01/28.01 x 100% = 42.88%
   Mass C in 150 g = 42.88/100 x 150.0 g = 64.32 g
3. Molar mass CH_4 = 12.01 + (4 x 1.01) = 16.05
   % C in CO_2 = 12.01/16.05 x 100% = 74.83%
   Mass C in 150 g = 74.83/100 x 150.0 g = 112.24 g
4. Molar mass $CaCO_3$ = 40.08 +12.01 + (3 x 16.00) = 100.09
   % C in CO_2 = 12.01/100.09 x 100% = 12.00%
   Mass C in 150 g = 12.00/100 x 150.0 g = 18.00 g
5. Molar mass CH_3COOH = (2 x12.01) + (2 x 16.00) + (4 x 1.01) = 60.05
   % C in CO_2 = (2 x 12.01)/60.05 x 100% = 39.98%
   Mass C in 150 g = 39.98/100 x 150.0 g = 59.98 g
6. Trick question! The symbol is Cl for chlorine and no C is present!

Activity 2.2.7:

1. From mass and molar mass one can calculate number of moles (n):
   n = mass/ RMM = 21.0 g/44.01 g = 0.477
   From n and volume at STP one can calculate actual volume:
   n = actual vol/molar vol so actual vol = n x molar vol = 0.477 x 22.41 dm^3
   = 10.7 dm^3
2. From actual vol and molar vol (at 25^oC, 1 atm) one can calculate n:
   n = actual vol/molar vol = 0.0573 dm^3/24.47 dm^3 = 1.40
   From n and RMM of NO one can calculate the mass of NO:
   n = mass/RMM so mass = n x RMM = 1.40 g.mol^{-1} x (14.01 + 16.00) g = 42.0 g
3. 6.02 x 10^{23} molecules of H_2 occupy 22.41 dm^3 at STP
   2.44 x 10^{19} molecules of H_2 occupy 22.41 dm^3 x (2.44 x 10^{19})/(6.02 x 10^{23}) at STP = 9.08 x 10^{-4} dm^3
4. 1 mole of O_2 has a mass of 2 x 16.00 g = 32.00 g and occupies 22.41 dm^3 at STP.
   55.0 g of O_2 would occupy 55.0 g/32.00 g x 22.41 dm^3 = 38.5 dm^3
5. 1 mole of N_2 has contains 6.02 x 10^{23} molecules and occupies 24.47 dm^3 at STP

5.0×10^{22} molecules of N_2 would occupy $5.0 \times 10^{22}/6.02 \times 10^{23} \times 24.47\ dm^3 = 2.03\ dm^3$

Activity 2.2.8:

1. RMM NaOH = 22.99 + 16.00 + 1.01 = 40.00 $g.mol^{-1}$
   Moles NaOH = mass/RMM = 17.0 g/ 40.00 $g.mol^{-1}$ = 0.425 mol
   Concentration = moles/volume = 0.425 mol/0.250 dm^3 = 1.70 $mol.dm^{!3}$
2. RMM $CuSO_2.5H_2O$ = 63.55 +32.06 + (7 x 16.00) + (10 x 1.01) = 217.7 $g.mol^{-1}$
   Moles $CuSO_2.5H_2O$ = mass/RMM = 300.0 g/217.7 $g.mol^{-1}$ = 1.38 mol
   Concentration = moles/volume = 1.38 mol/750 x 10^{-3} dm^3 = 1.84 $mol.dm^{!3}$
3. RMM HCl = 1.01 + 35.45 = 36.46 $g.mol^{-1}$
   Moles HCl = mass/RMM = 8.3 g/36.46 $g.mol^{-1}$ = 0.228 mol
   Volume = moles/concentration = 0.228 mol/ 6.0 M = 0.038 dm^3 = 38 ml
4. RMM NaCl = 22.99 + 35.45 = 58.44 $g.mol^{-1}$
   Moles present = concentration x volume = 3.2 $mol.dm^{!3}$ x 50.0 x 10^{-3} $dm^{!3}$ = 0.16 moles
   Mass present = moles x RMM = 0.16 mol x 58.44 $g.mol^{-1}$ = 9.4 g
5. RMM $CaCl_2$ = 40.08 + (2 x 35.45) = 110.98 $g.mol^{-1}$
   Moles $CaCl_2$ = mass/RMM = 4.55 g/110.98 $g.mol^{-1}$ = 0.04 mol
   Concentration = moles/volume = 0.04 mol/0.150 dm^3 = 0.27 $mol.dm^{!3}$
6. RMM $FeCl_3$ = 55.85 + (3 x 35.45) = 162.2 $g.mol^{-1}$
   Moles present = concentration x volume = 0.200 $mol.dm^{!3}$ x 2.00 $dm^{!3}$ = 0.400 moles
   Mass present = moles x RMM = 0.400 mol x 162.2 $g.mol^{-1}$ = 64.9 g

Activity 2.2.9:

1. CH_2
2. CH_2O
3. H_2O
4. CH_2

Activity 2.2.10:

1.

Elements	C	H	O
% mass	40.0	6.7	53.3
Mass (g) in 100g sample	40.0/100 x 100g = 40.0	6.7/100 x 100g = 6.7	53.3/100 x 100g = 53.3
Molar mass (g/mole)	12.01	1.01	16.00
No of moles = mass/molar mass	40.0/12.01 = 3.33	6.7/1.008 = 6.65	53.3/16.00 = 3.34
Divide both sides by lower value to give a whole number of 1 for one element at least	3.33/3.33 = 1	6.65/3.33 = 2	3.34/3.33 = 1
Empirical formula	CH_2O		

EFM = 12.01 + 1.01 + 1.01 = 14.03 g/mole

No of multiples in molecular formula = Molar mass/EFM = 60.0 g/mole/29.02 g/mole = 2

Molecular formula = $C_2H_4O_2$

2. A hydrocarbon is made from C and H atoms only. If 85.7% is C, 100 – 85.7= 14.3% is H

Elements	C	H
% mass	85.7	14.3
Mass (g) in 100g sample	85.7/100 x 100g = 85.7	14.3/100 x 100g = 14.3

Molar mass (g/mole)	12.01	1.01
No of moles = mass/molar mass	85.7/12.01 = 7.14	14.3/1.008 = 14.19
Divide both sides by lower value to give a whole number of 1 for one element at least	7.14/7.14= 1	14.19/7.14= 2
Empirical formula	CH_2	

EFM = 12.01 + 1.01 + 16.00 = 29.02 g/mole

No of multiples in molecular formula = Molar mass/EFM = 84.0 g/mole/14.03 g/mole = 6

Molecular formula = C_6H_{12}

3.

Elements	Fe	O
% mass	72.3	27.7
Mass (g) in 100g sample	72.3/100 x 100g = 72.3	27.7/100 x 100g = 27.7
Molar mass (g/mole)	55.85	16.00
No of moles = mass/molar mass	72.3/55.85 = 1.29	27.7/16.00 = 1.73
Divide both sides by lower value to give a whole number	1.29/1.29= 1	1.73/1.29= 1.34

of 1 for one element at least		
To convert both numbers to whole numbers, x3	1 x 2 = 3	1.34 x 3 = 4
Empirical formula	Fe_3O_4	

EFM = (55.85 x 3) + (16.00 x 4) = 231.55 g/mole

No of multiples in molecular formula = Molar mass/EFM = 231.4 g/mole/231.55 g/mole = 1

Molecular formula = Fe_3O_4

4.

Elements	C	H	O
% mass	40.0	5.7	53.3
Mass (g) in 100g sample	40.0/100 x 100g = 40.0	5.7/100 x 100g = 5.7	53.3/100 x 100g = 53.3
Molar mass (g/mole)	12.01	1.01	16.00
No of moles = mass/molar mass	40.0/12.01 = 3.33	5.7/1.01 = 5.64	53.3/16.00 = 3.33
Divide both sides by lower value to give a whole number of 1 for one element at least	3.33/3.33 = 1	5.64/3.33 = 1.7	3.33/3.33 = 1
To convert both numbers to	3	5	3

whole numbers, x3			
Empirical formula	$C_3H_5O_3$		

EFM = (12.01 x 3) + (1.01 x 5) + (16.0 x 3) = 89.08 g/mole

No of multiples in molecular formula = Molar mass/EFM = 175.0 g/mole/89.08 g/mole = 1.96 = 2

Molecular formula = $C_6H_{10}O_6$

5.

Elements	N	H
% mass	87.4	12.6
Mass (g) in 100g sample	87.4/100 x 100g = 87.4	12.6/100 x 100g = 12.6
Molar mass (g/mole)	14.01	1.01
No of moles = mass/molar mass	87.4/14.01 = 6.24	12.6/1.01 = 12.48
Divide both sides by lower value to give a whole number of 1 for one element at least	6.24/6.24 = 1	12.48/6.24= 2
Empirical formula	NH_2	

EFM = 14.01 + (1.01 x 2) = 16.02 g/mole

No of multiples in molecular formula = Molar mass/EFM = 32.05 g/mole/16.02 g/mole = 2

Molecular formula = N_2H_4

Activity 2.2.11:

2.
   a. 1 meat patty + 3 lettuce leaves + 2 slices of tomato = 1 hamburger
   b.
      i. 4 hamburger buns
      ii. 4 meat patties
      iii. 4 x 3 = 12 lettuce leaves
      iv. 4 x 2 = 8 slices of tomato
   c.
      i. Three hamburgers possible. There are too many buns for 3 meat patties which need 3 buns, 3 x 3 = 9 lettuce leaves and 3 x 2 = 6 tomato slices. A bun, 3 lettuce leaves and 2 slices of tomato will be left over.
      ii. Four hamburgers possible. Four meat patties need 4 buns, 4 x 3 = 12 lettuce leaves and 4 x 2 = 8 tomato slices. All the ingredients will be used up.
      iii. Three hamburgers possible. All the buns and patties will be used up. Nine (3 x 3) lettuce leaves and 3 x 2 = 6 tomato slices will be used. Three lettuce leaves and 2 slices of tomato will be left over.
      iv. Three hamburgers possible. Four buns and patties need 4 x 3 = 12 lettuce leaves and 4 x 2 = 8 slices tomato. There are too few of both. For 3 hamburgers need 3 buns, 3 x 3 = 9 lettuce leaves and 3 x 2 = 6 slices tomato. So left over will be 1 bun, 1 patty, 2 lettuce leaves and 3 tomato slices.
   d. Number of hamburger patties possible = total mass mince/ mass of 1 patty = 1500 x 1000 g/200g = 7500. Therefore 7500 hamburgers can be made from 1500 kg mince.
   e. Percentage product (hamburgers) made
      = actual product/expected product x 100%
      = 7/10 x 100 = 70%
   f. All the ingredients have to be present in the correct proportion to use up all of the ingredients with no waste. The proportion is: 1 bun:1 patty: 3 lettuce leaves:2 tomato slices.

g. The mass of mince determines the number of patties possible. The same is true of the mole and relative molar mass and Avogadro's number – 1 molar mass contains 6.02×10^{23} particles so any other mass will contain a proportion of particles determined by the ratio of that mass to the molar mass.
h. Burning of patties leads to wastage – other ingredients can no longer be used up. SO this determines the percentage yield which will be lower than the originally expected yield. An employee who burns patties would probably be fired because of wastage of ingredients and therefore money (profits).

3.

a. H_2 represents 1 mole of hydrogen gas which contains 2 atoms of hydrogen
b. O_2 represents 1 mole of oxygen gas which contains 2 atoms of oxygen
c. H_2O represents 1 mole of water which contains 2 atoms of hydrogen and 1 atom of oxygen
d. State symbols: g means gas and l means liquid
e. The equation is not balanced.
Balanced equation: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
f. In a balanced equation the Law of Conservation of Mass is obeyed since all the atoms on the LHS are accounted for on the RHS
g. The reaction ratio for $H_2:O_2$ is 2:1
h. One mole of oxygen requires 2 moles of hydrogen to react completely
i. Two moles of product would be expected
j. The mass needed can be worked out from the molar mass.
mass H needed = 2 x (1.01 x 2) = 4.02 g
mass O needed = 16.00 x 2 = 32.00 g
k. Mass of product to be expected =
2 x (1.01 x 2) + (16.00 x 2) = 36.02g
l. One mole hydrogen occupies $22.41dm^3$
Two moles hydrogen are required = 2 x $22.41dm^3$ = $44.82\ dm^3$
One mole of oxygen is needed = $22.41dm^3$
m. 4 moles of hydrogen could react with 2 moles of oxygen. With only 1 mole of oxygen present only 2 moles of hydrogen would be used up. So oxygen limits the amount of product that can be formed. It is the limiting reactant.

n. 2 moles of hydrogen could react with 1 mole of oxygen to produce 2 moles of water (from the balanced equation). Five moles of oxygen would be left over and hydrogen would be the limiting reactant.

Activity 2.2.12:

1. 1 mole of H_2SO_4 can give 1 mole of Na_2SO_4
   5 mole of H_2SO_4 can give 5 mole of Na_2SO_4
2. 1 mole of H_2SO_4 requires 2 moles of NaOH
   3 mole of H_2SO_4 requires 6 moles of NaOH
3. 6 moles of NaOH are needed (question 2)
   RMM of NaOH = 22.99 + 16.00 + 1.01 = 40.00 $g.mol^{-1}$
   Mass of 6 moles = 6 x 40.00 g = 240.0 g
4. 1 mole of H_2SO_4 requires 2 moles of NaOH
   20 moles of NaOH is excess NaOH – only 2 moles are required for the acid present. 18 moles of NaOH will be left over.
5. 1 mole of H_2SO_4 requires 2 moles of NaOH.
   NaOH is present in excess – only 2 moles of NaOH are needed.
   1 mole of H_2SO_4 can give 1 mole of Na_2SO_4
6. Yes 5-2 = 3 moles of NaOH will be left over.
   RMM of NaOH = 22.99 + 16.00 + 1.01 = 40.00 $g.mol^{-1}$
   Mass of 3 moles = 3 x 40.00 g = 120.0 g
7. 1 mole of H_2SO_4 and 2 moles of NaOH give 1 mole of Na_2SO_4
   RMM of Na_2SO_4 = (2 x 22.99) + 32.07 + (4 x 16.00) = 142.1 $g.mol^{-1}$
   Mass of 1 mole of Na_2SO_4 = 1 x 142.1 = 142.1 g
8. % yield = actual mass/theoretical mass x 100%
   = 131.5 g/142.1 g x 100% = 92.5%

Answers 2.2.13:

1.
   a. 30.97 amu
   b. 12.01 g
   c. 65.39 g
   d. 238.03 amu
   e. 39.10 g

2.

a. 1 mole contains 6.02×10^{23} atoms
   2.3 moles contain $2.3 \times 6.02 \times 10^{23}$ atoms = 1.38×10^{24}
b. 1 mole contains 6.02×10^{23} molecules
   4.13 moles contain $4.13 \times 6.02 \times 10^{23}$ molecules = 2.49×10^{24}

3.

a. RMM Ag_2SO_4 = (2 x 107.87) + 32.07 + (4 x 16.00) $g.mol^{-1}$
   = 311.8 $g.mol^{-1}$
b. RMM SF_6 = 32.07 + (6 x 19.00) $g.mol^{-1}$
   = 146.1 $g.mol^{-1}$
c. RMM $Mn(NO_3)_2$ = 54.94 + (2 x 14.01) + (6 x 16.00) $g.mol^{-1}$
   = 179.0 $g.mol^{-1}$
d. RMM N_2O_5 = (2 x 14.01) + (5 x 16.00) $g.mol^{-1}$
   = 110.0 $g.mol^{-1}$
e. RMM $Sr_3(PO_4)_2$ = (3 x 87.62) + (2 x 30.97) + (8 x 16.00) $g.mol^{-1}$
   = 452.8 $g.mol^{-1}$

4.

a. RMM Fe_2O_3 = (2 x 55.85) + (3 x 16.00) $g.mol^{-1}$
   = 159.7 $g.mol^{-1}$
   % Fe = (2 x 55.85)/159.7 x 100%
   = 69.9%
   % O = (3 x 16.00)/159.7 x 100%
   = 30.1%
b. RMM C_8H_{18} = (8 x 12.01) + (18 x 1.01) $g.mol^{-1}$
   = 114.3 $g.mol^{-1}$
   % C = (8 x 12.01)/114.3 x 100%
   = 84.1%
   % H = (18 x 1.01)/114.3 x 100%
   = 15.9%

5. RMM Fe_2O_3 = (2 x 55.85) + (3 x 16.00) $g.mol^{-1}$
   = 159.7 $g.mol^{-1}$
   % Fe = (2 x 55.85)/159.7 x 100%
   = 69.9%
   Mass of Fe in 1000.0 kg of iron oxide = 69.9/100 x 1000.0 kg

= 699.0 kg

6. STP means a temperature of 0^oC (273 K) and a pressure of 1 atmosphere (100 kPa)

7. Molar volume is the volume occupied by one mole of **any** gas at a particular temperature and pressure.

8. RMM CO_2 = 12.01 + (2 x 16.00) = 44.01 $g.mol^{-1}$
   Moles CO_2 = mass/RMM = 100.0 g/44.01 $g.mol^{-1}$
   = 2.27 mol
   1 mole CO_2 contains 6.02×10^{23} molecules
   2.27 moles contains $2.27 \times 6.02 \times 10^{23}$ molecules = 1.37×10^{24} molecules

9. At 0^oC and 1 atm pressure, 1 mole of gas will occupy 22.4 dm^3
   If the volume is 1.00 dm^3 the number of moles = 1 x 1.00/22.4 = 0.045

10. 2.0 moles of K_2SO_4
    a. contains 2 x 2.0 = 4.0 moles of K atoms
    b. contains 2 x 1.0 = 2.0 moles of S atoms = 2.0 x 32.07 g of S atoms
       = 64.1 g of S atoms
    c. contains 4 x 2.0 = 8.0 moles of O atoms = $8.0 \times 6.02 \times 10^{23}$ O atoms
       = 48.2×10^{23} O atoms = 4.8×10^{24} O atoms
    d. contains 2 x 1.0 = 4.0 moles of formula units of compound
       = $4.0 \times 6.02 \times 10^{23}$ formula units = 2.4×10^{24} formula units
    e. RMM K_2SO_4 = (2 x 39.10) + 32.07 + (4 x 16.00) = 174.3 $g.mol^{-1}$
       Mass of 2.0 moles = 2.0 x 174.3 g = 348.6 g

11.
    a. RMM NaCl = 22.99 + 35.45 $g.mol^{-1}$ = 58.44 $g.mol^{-1}$
       Moles NaCl = 1.75 g/58.44 $g.mol^{-1}$ = 0.03 moles
       Concentration = moles/volume = 0.03 mol/0.363.5 dm^3
       = 0.08 $mol.dm^{!3}$

b. RMM $C_{12}H_{22}O_6$ = (12 x 12.01) + (22 x 1.01) + (6 x 16.00) g.mol^{-1} = 262.34 g.mol^{-1}
   Moles $C_{12}H_{22}O_6$ = 20.0 g/262.34 g.mol^{-1} = 0.08 moles
   Concentration = moles/volume = 0.08 mol/0.250 dm^3
   = 0.32 mol.dm$^{!3}$

12. Moles of sugar present = 2.5
    RMM of sugar = 262.34 g.mol^{-1}
    Mass of sugar = moles x RMM = 2.5 x 262.34 g
    = 655.9 g

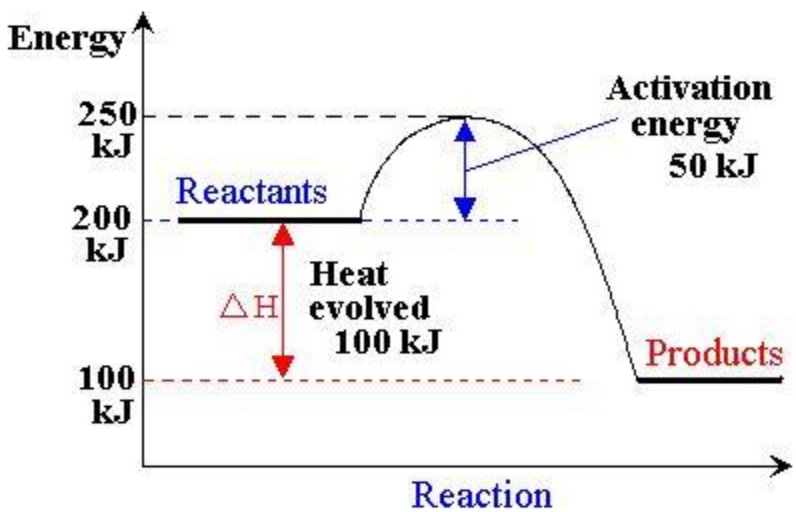
13.
   a. 6 moles
   b. Molar volume at STP = 22.4 dm^3
      6 moles would occupy 6 x 22.4 dm^3 = 134.4 dm^3
   c. 5 moles CH_4(g) need 10 moles O_2(g)
      7 moles O_2(g) are available, so O_2(g) is limiting
      7 moles O_2(g) will convert 7/2 = 3.5 moles CH_4(g)
      3.5 moles CH_4(g) would produce 3.5 moles CO_2(g)
   d. RMM O_2 = (2 x 16.00) = 32.00 g.mol^{-1}
      Moles O_2 = mass/RMM = 1000.0 g/ 32.00 g.mol^{-1}
      = 31.25 moles
      31.25 moles O_2 will convert 31.25/2 moles CH_4 = 15.63 moles
      RMM CH_4 = 12.01 + (4 x 1.01) g.mol^{-1} = 18.05 g.mol^{-1}
      Mass of CH_4 = moles x RMM = 15.63 g x 18.05 g.mol^{-1}
      = 282.1 g

14. Molar mass $CaCO_3$ = 40.08 + 12.01 + (3 x 16.00) g/mole
    = 100.09 g/mole
    Molar mass CaO = 40.08 + 16.00 g/mol = 56.08 g/mole
    Ratio of CaO: $CaCO_3$ = 56.08:100.09 (56.08/100.09)
    Number of grams $CaCO_3$ present = 20.7 g
    Theoretical mass of CaO possible = 20.7g x 56.08/100.09
    = 11.6 g
    Actual yield = 6.81 g
    % yield = actual yield /theoretical yield x 100%
    = 6.81/11.6 x 100 %
    = 58.7 %

Activity 2.2.14

1. D
2. A
3. Activation energy (E_a) is the minimum amount of energy for a reaction to occur. It is the amount of energy required to create an activated complex.
4. A catalyst changes the reaction mechanism, in the process lowering the activation energy.
5. Increase concentration by distillation of a solvent
   Increase concentration by increasing pressure of a gas,
   Increase temperature
   Add a catalyst

6. The reaction is exothermic. The ΔH is -100 KJ/mol which means heat is released.



7. Add a catalyst

Activity 2.2.15:

1.
   a. The reaction would go to the right hand side (RHS)
   b. The reaction would go to the left hand side (LHS)

c. The reaction would go to the right hand side (RHS) – in the direction of fewer moles.
d. The reaction would go to the left hand side (LHS) – in the direction of more moles.
e. There would be no change.
f. The reaction would go to the left hand side (LHS)
g. The reaction would go to the right hand side (RHS)
h. A catalyst does not affect the equilibrium – it increases reaction rate.
i. You could increase the concentration of A or B and reduce the temperature. If gases were involved a pressure change could also be made.

2.

a. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad -\Delta H$
b. Towards the RHS
c. Towards the LHS as the reaction is exothermic so the shift is towards the endothermic side to lower heat released.
d. Increasing pressure would drive the reaction to the RHS which is the side with fewer moles of gas present.
e. Removing NH_3 would pull the reaction to the RHS.
f. A catalyst would increase the rate at which equilibrium is reached but would not shift the equilibrium.
g. Not too high temperature, high pressure, catalyst, removing product as it is formed.

Answers 2.2.16:

1. A reaction that is in dynamic equilibrium is one in which the rate of the forward reaction and the rate of the reverse reaction are equal, so the concentrations of reactants and products no longer change.

2. Le Chatelier’s Principle states that if a reversible reaction that is in a state of dynamic equilibrium is disturbed by changing the conditions, the reaction will do what it can to oppose that change.

3. For a reversible reaction between gases, if the forward reaction is exothermic raising the temperature?

4. For a reversible reaction between gases, if the forward reaction is endothermic raising the temperature increases the yield.

5.
    a. Equilibrium remains the same and CO concentration does not change

    b. Equilibrium moves to the left and CO concentration increases
    c. Equilibrium moves to the right and CO concentration decreases
    d. Equilibrium moves to the right and CO concentration decreases

6. The Haber Process

$$N_2(g) \quad + \quad 3H_2(g) \quad \leftrightarrow \quad 2NH_3(g)$$

Activity 2.2.17:

1. Sulfuric acid: H_2SO_4
   Table salt: NaCl
   Sodium hydroxide: NaOH
   Hydrochloric acid: HCl
   Potassium hydroxide: KOH
2. In acids H is the common element, The common ion would be H^+
3. In bases O and H are common elements. The common ion would be OH^-
4. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
   The acid and the base react with each other to produce salt and water. Water is neutral and so is salt. So, as more and more NaOH is added to the HCl the point will be reached where the solution is neutral. If still more NaOH is added it will become an excess which cannot be neutralised by the acid any longer and the solution will become basic, turning the litmus paper blue.

Answers 2.2 18:

1. $HNO_3(aq) \quad + \quad KOH\ (aq) \quad \rightarrow \quad KNO_3(aq) \quad + \quad H_2O(l)$

2. $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
3. $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
4. $2HCl(aq) + Mg(OH)_2(s) \rightarrow MgCl_2(aq) + 2H_2O(l)$
5. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Reactions 1, 3 and 4 are neutralization reactions. Water is a product in each of these reactions.

The salts are potassium nitrate, KNO_3, sodium sulfate, Na_2SO_4 and magnesium chloride, $MgCl_2$

Answers 2.2 19:

1.
    a. An acid is a substance that releases hydrogen (H^+) ions when placed in water

    b. A base is a substance that releases hydroxide (OH^-) ions when placed in water

    c. An alkali is a base which is soluble in water

    d. A salt is the product of a reaction between an acid and a base

    e. A neutral solution is one which is neither acidic nor alkaline

2.
    a. One can use litmus paper. Place red and blue litmus paper into the solution/liquid. If the red paper turns blue and the blue paper remains blue, the solution is a base. If the blue paper turns red and the red paper remains red, the solution is an acid. Litmus papers are not really suitable for measuring neutral solutions.
    b. The alkaline solution and the acidic solution start to react with each other. Initially there is too little alkaline solution to neutralise all the acid so the litmus paper would stay reddish in colour. As more alkaline solution is added more and more of the acid is neutralised until there is neither acid nor base in the mixture. As more alkaline solution is added the solution will

become more alkaline because there is no acid left to neutralise it and the litmus paper will turn blue.

Activity 2.2.20: Answer the following multiple choice questions:

1. Which of these acids is most likely to be dangerous? B
2. Which statement about bases is true? B
3. Which statement about alkalis is true? B
4. Litmus paper that is placed in an acidic solution: C
5. A liquid is tested for pH using a universal indicator. The colour shown is green. This means that the liquid is: A
6. A liquid that has a pH of 6.5 is: B
7. The contents of your stomach have a pH of 1. What does this mean? C
8. When an acid reacts with a metal hydroxide the products formed are: A
9. The products of a reaction with acid are a salt, carbon dioxide and water. What is the substance reacting with the acid? B
10. Which acid could be used to manufacture a fertilizer called ammonium nitrate? C
11. What gas is produced when magnesium reacts with sulfuric acid? C
12. What salt is formed when copper oxide reacts with nitric acid? B
13. A Brønsted-Lowry base is: B
14. Which of the following statements is true? B
15. A hydrogen ion (H^+) is the same as a: A