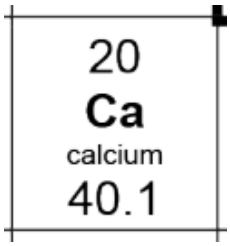
Revision Exercise on the 1st Half-term of Chemistry



1. Calcium, Ca, is a reactive metal in group 2 of the periodic table.
   a) What is the atomic number of Ca? …20…
   b) Define *relative atomic mass*.

   ……the average mass of atoms of an element compared to 1/12 the mass of a ^{12}C atom…… ……..

   c) What is the electronic configuration of the calcium, atom? Give the **full** configuration.

   ……$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ ……

   d) What block of the periodic table is Ca in? ….s…..
   e) Calcium has 26 known isotopes. After Ca-40, the isotope Ca-44 is the second most abundant with an abundance of 2.09%.
      i) How many protons does **Ca-44** have? 20
      ii) How many neutrons does **Ca-44** have? 24
      iii) How many electrons does $^{44}Ca^{2+}$ have? 18
2. Calcium is a reactive metal in group 2 of the periodic table. It reacts in water to give a solution calcium hydroxide and hydrogen.
   a) Write a word equation for the reaction between calcium and water.
      …… calcium + water ➔ calcium hydroxide + hydrogen……
   b) Write a symbol equation for the reaction between calcium and water.
      ……$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2\,(g)}$……
   c) 2.44g of calcium was added to 750cm^3 of de-ionised water. The hydrogen that was evolved was collected.
      i) Calculate the number of moles present in 2.44g of calcium. Give your answer in **standard form** and to the appropriate number of **significant figures**. Include the **units** 2.44g / 40.1 g mol^{-1} = 6.08 x 10^{-2} mol

      Answer……6.08 x 10^{-2} mol

      ii) Calculate the concentration of the calcium hydroxide solution produced if you assume that all of the calcium hydroxide is dissolved in the 750cm^3 of water.

      6.08 x 10^{-2} mol / 0.750 dm^{-3} = 0.0811 mol dm^{-3}

      Answer…8.11 x 10^{-2} or 0.0811 mol dm^{-3}

      iii) The hydrogen gas was collected at 26°C and the pressure of the hydrogen was recorded as 102kPa. Calculate the volume of hydrogen collected under these conditions. Give the units in your answer. R=8.314 J mol^{-1} K^{-1}

      T = 26 + 273 = 299K

      P = 102 000 Pa

      V=nRT/P = 6.08x10^{-2} x 8.314 x 299/102 000 = 1.48 x 10^{-3} m^3

      or = 1.48 dm^3

      or = 1.48 x 10^3 cm^3

      Answer……

3. You realise that the calcium hydroxide produced has not all dissolved because you observe large amounts of white precipitate which you correctly assume to be undissolved calcium hydroxide. You decide to work out the solubility of calcium hydroxide in water at 20°C.

Solubility is typically measured in g/100cm^3 of solution

One method to do this could be to filter off the precipitate of calcium hydroxide, wash it and dry it to constant mass. You could then work out how much remained in solution. However, the precipitate is very difficult to filter. And, washing the precipitate with water washes away some the calcium hydroxide by dissolving it.

So, you decide to determine the concentration of the calcium hydroxide solution (also known by the familiar name, lime water) by titration with sulfuric acid.

- concentration of sulfuric acid is 0.0240 mol dm^{-3}
- volume of calcium hydroxide solution used in each titration was 25.0 cm^3

Your results are shown below:

	Run 1	Run 2	Run 3	Run 4
Final volume/ cm^3	24.35	47.50	26.60	49.85
Initial volume/ cm^3	0.00	24.35	0.50	26.60
Titre/ cm^3	24.35	**23.15**	24.10	**23.25**

a) Complete the table by entering the missing titre values.

b) Calculate the mean titre value.

Answer…23.20…

c) Write a word equation for the reaction between calcium hydroxide and sulfuric acid.

……calcium hydroxide + sulfuric acid ➔ calcium sulfate + water……..

d) Write a symbol equation for the reaction between calcium hydroxide and sulfuric acid.

…… $Ca(OH)_2$ + H_2SO_4 ➔ $CaSO_4$ + $2H_2O$……..

e) You now have sufficient information to calculate the **solubility** of calcium hydroxide in g/100cm^3.

Attempt to do this without further prompting.

If you need **more guidance**, follow the steps (i)-(v) below.

Solubility of calcium hydroxide 0.165 … g/100cm^3

i) Calculate the number of moles of sulfuric acid used in each titration.

$23.20/1000\ dm^3 \times 0.240\ mol\ dm^{-3} = 5.57 \times 10^{-4}\ mol$

Answer……5.57×10^{-4} mol

ii) Calculate the number of moles of calcium hydroxide used in each titration.

Ratio from balanced equation is 1:1 so 5.57×10^{-4} mol

Answer……5.57×10^{-4} mol

iii) Calculate the number of moles of calcium hydroxide in each $100cm^3$ of solution.

5.57×10^{-4} mol x 4 =

Answer……2.23×10^{-3} mol

iv) Calculate the mass calcium hydroxide in each $100cm^3$ of solution.

Molar mass of calcium hydroxide = (40.1 + (17 x 2))= 74.1 g mol^{-1}

2.23×10^{-3} mol x 74.1 g mol^{-1} =

Answer……0.165 g

v) So, what is the solubility of calcium hydroxide?

Solubility of calcium hydroxide …0.165 … g/$100cm^3$

4. 100cm^3 of the calcium hydroxide solution were neutralised with sulfuric acid to produce a solution of calcium sulfate. This solution was heated **gently** to evaporate the solution to give crystals of constant mass.

   If you didn't manage to obtain an answer for the solubility of calcium hydroxide, assume that the solubility of the calcium hydroxide is 0.165 g per 100cm^{-3}.

   a) Calculate the theoretical mass of pure dry calcium sulfate that you should obtain.

   $2.23 \times 10^{-3} \times 136.1 \text{ g mol}^{-1} = 0.303\text{g}$

   Answer……0.303g

   b) The actual mass of dry crystals that was obtained was 0.383g.

   You decide that the calcium sulfate has crystallised as a hydrate. Determine the formula of the hydrate.

   Difference = **0.080g** This is due to water.

   Moles of water = 0.080/18.0 = **4.46×10^{-3} mol**

   Ratio of anhydrous compound : water

   2.23×10^{-3} mol : 4.46×10^{-3} mol

   Answer…$CaSO_4 \bullet 2H_2O$

   a) ***Plaster of Paris*** is traditionally used to coat bandages in casts for broken bones.

   Plaster of Paris is the hemi hydrate of calcium sulfate. It has the chemical formula $CaSO_4 \bullet 0.5\ H_2O$.

   You decide to produce a small sample of ***Plaster of Paris*** by gently dehydrating the original hydrate (0.383g) until it achieves the desired mass of the hemi hydrate.

   Calculate the mass of the sample that you would need to achieve before you stop the dehydration.

   If you didn't manage to work out the formula of the original hydrate, it was $CaSO_4 \bullet 2\ H_2O$.

   Mol of water that must be removed by dehydration 2.23×10^{-3} mol x 1.5 = **3.34×10^{-3} mol**

   Mass of water to be removed = 3.34×10^{-3} mol x 18.0 g mol^{-1} = **0.0601g**

   Target mass of hemi hydrate = 0.383g - 0.0601g = **0.323g**

   OR

   2.23×10^{-3} mol x molar mass of hemi-hydrate = 2.23×10^{-3} mol x 145.1 g/mol = **0.323g**

   Answer 0.323g

5. You take another 100cm^3 of the original saturated calcium hydroxide solution. You decide to exhale through the solution to fully react the calcium hydroxide solution with carbon dioxide gas (from exhaled air) by conversion to the precipitate of calcium carbonate.

   a) Write a word equation for the reaction between the base, calcium hydroxide solution and carbon dioxide which is as acidic oxide.

   ……calcium hydroxide + water ➔ calcium carbonate + water……

   b) Write a symbol equation for the reaction between calcium hydroxide solution and carbon dioxide.

   …….. $Ca(OH)_2 + CO_2$ ➔ $CaCO_3 + H_20$ ……

   c) The percentage CO_2 in exhaled air is around 4%.

   The molar gas volume under these conditions is 25.2 dm^3 mol^{-1}.

   The average volume of exhaled air, at rest, is 500cm^3. Assume that you are average. (Sorry!)

   Calculate the minimum number of full breaths that you would need to exhale in order to fully neutralise the calcium hydroxide solution.

   Moles of $Ca(OH)_2$ in 100cm^3 is 0.165/40.1 = **2.23 x 10^{-3} mol.**
   Moles of CO_2 that must react = **2.23 x 10^{-3} mol.**
   Volume of CO_2 that must react 2.23 x 10^{-3} mol x 25.2 dm^3 mol^{-1} = **0.0561 dm^3.**
   Volume of exhaled air must be 0.0561 dm^{3}x 100/4 **=1.40 dm^3**
   Number of breaths1.40 dm^3 / 0.500 dm^3 per breath = **2.81 breaths**
   Therefore **3 full breaths** required

   Answer **3 breaths** required

6. Calculate the atom economy for the process that produces **calcium carbonate as the desired product**.

   (100.1/100.1+18) x 100% = **84.8%**

   Answer……84.8%.

7. You decide to filter and wash the calcium carbonate precipitate produced when you exhaled through 100cm^3 of saturated calcium hydroxide solution.

   After drying to constant mass, you have a mass of 164mg of calcium carbonate.

   Calculate the percentage yield.

   Theoretical yield = 2.23 x 10^{-3} mol x 100.1 = **0.223g**

   Actual yield = 0.164g

   % yield = 0.164/ 0.223 x 100% = **73.5%**

   Answer…73.5%