Another challenging Extended Revision Exercise that tests a variety of Y12 skills. ANSWERS

In all answers, show your working!

1. Iron (II) sulfate can be found in several named minerals which differ by the level of hydration. Write a general formula for these compounds, using ***x*** to represent the number of waters of crystallisation.

   $FeSO_4 \cdot x\,H_2O$

   8.71g of one of the minerals was dehydrated to constant mass
   The mass of anhydrous crystals produced was found to be 5.91g
   Show that the mineral form of the hydrate was Rozenite (the tetra hydrate)

   M_r of anhydrous form = 152 M_r of hydrate = 224 (no UNITS!)
   Moles of hydrate = 8.71/ 224 = 0.0389mol
   0.0389 x 152 = 5.91g

2. This dehydrated sample was dissolved in de-ionised water and made up accurately to 100cm^3 in a graduated flask. This solution was used to determine the concentration of a **sodium chlorate(I)** solution.
   The iron (II) solution was titrated against 20.0 cm^3 aliquots (portions) of a **chlorate(I)** solution. The mean titre was found to be 26.70 cm^3

   a) Write the chemical formula of **chlorate (I)** ion ClO^-

   b) What is the **oxidation number** (state) of chlorine in this **chlorate (I)** ion +1

   c) **chlorate (I)** ion is a good oxidising agent and the chlorine becomes reduced to the **chloride ion**

      Write the chemical formula of the **chloride** ion Cl^-

   d) What is the oxidation number (state) of chlorine in this **chloride** ion -1

   e) Using these oxidation numbers, complete the **half-equation** showing the reduction of the chlorate (I) ion to chloride

      $$ClO^- + 2e^- + 2H^+ \rightarrow Cl^- + H_2O$$

   f) The iron (II) ions are oxidised to iron (III) ions by chlorate in the titration.
      Using the oxidation numbers, complete the **half-equation** showing the oxidation of the iron (II).

      $$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

   g) Write a full balanced **redox equation** for this reaction. **Remember**, you need to combine the two equations in such a way the **number of electrons on both sides cancel out.** Hint, multiply ones of the equations before adding together
      The equation below contains all of the chemicals on the left and right of the 2 half-equations. The electrons have cancelled. The iron half-equation has been doubled.

$ClO^- \quad + \quad 2Fe^{2+} \quad + \quad 2H^+ \quad \rightarrow \quad Cl^- \quad + \quad H_2O \quad + 2Fe^{3+}$

h) Now you have found the **ratio of reactants** from the redox equation above, determine the concentration of this chlorate (I) solution.

Total original moles of iron (II) sulfate dissolved = 0.0389 mol

moles of iron (II) sulfate dissolved **per titration** = 0.0389/5 = 7.78×10^{-3}mol

moles of chlorate(I) **per titration** =$7.78 \times 10^{-3} / 2$ = 3.89×10^{-3} mol

This is dissolved in 26.70cm^3 of solution (the titre!) So,

c = n/v conc= $3.89 \times 10^{-3} / 26.70 \times 10^{-3}$ = **0.146 mol** dm^{-3}

3. The **aqueous chloride** that is produced in the titrations in part 2 could be oxidised back to chlorine gas by reacting it with a powerful oxidising agent.
Write the **half-equation** showing the oxidation of chloride to chlorine

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

The chlorine that was produced was collected in a gas syringe. Calculate the volume of the gas which was collected at 299K and at an atmospheric pressure of 101 000Pa. Express your answer in **cubic decimeters**, to **1 decimal place** and in **standard form.**

Moles of **chlorine made** is half that of **chloride produced** in titrations.
Moles of **chloride produced** in titration is same as **chlorate used** up in titration
= 3.89×10^{-3}mol
So, **moles of chlorine made** is $3.89 \times 10^{-3}/ 2$ = 1.95×10^{-3} **mol** = n
V = nRT/p

$$\frac{1.95 \times 10^{-3} \times 8.314 \times 299}{101000} = 4.80 \times 10^{-5} m^3 = 0.0480\ dm^{-3} = \mathbf{4.8 \times 10^{-2}\ dm^{-3}}$$

The volume of chlorine collected was significantly lower than expected. Give one possible reason, other than human error or leaks in the apparatus.

Solubility of chlorine in water means that some of the chlorine has dissolved in the water

4. The chlorine in the gas syringe was then repeatedly passed through an aqueous solution of sodium bromide to produce bromine (this is how bromine is extracted industrially from sea water).

a) What would be the main observation during the reaction?
Solution turns brown/yellow/orange (not red!)

b) What is the name of this specific redox reaction? displacement

c) Write an ionic equation for the reaction.

Cl_2 + $2Br^-$ ➔ Br_2 + $2Cl^-$

d) What mass of sodium bromide would be necessary to consume all the chlorine **BUT** not be in excess?

So, **moles of chlorine made** = 1.95 x 10 $^{-3}$ mol

So, **moles of bromide** (therefore sodium bromide) = 1.95 x 10 $^{-3}$ x 2 =**3.89 x 10 $^{-3}$** mol

So, **mass of sodium bromide** = 3.89 x 10 $^{-3}$ x 103 = 0.400g

e) Calculate the **atom economy** for the process if the bromine is the desired product. *Care! You can't use the ionic equation! Think why?*

160/(160 + (2x58.5)) x 100%= 57.7% (2NaCl are made so 2 x 58.5!)

f) Calculate the **percentage by mass** of bromine in sodium bromide.

79.9/(79.9 + 23.0) x 100% = 77.6%

5. The bromine can be extracted carefully from the water to produce pure bromine liquid. This can be used to produce bromomethane by reaction with natural gas (methane). For the reaction to occur between these two chemicals, the reaction must be started by applying which condition?

UV light

What is the name of this process that 'kick-starts' the reaction? Initiation

Write a overall chemical equation for this process

CH_4 + Br_2 ➔ CH_3Br + HBr

Now complete the propagation steps for the process.

Draw the displayed formulae for 1 unwanted product formed in the reaction and explain how it got there!

Any of **CH_2Br_2 / $CHBr_3$ / CBr_4** Reason **further substitution reactions**

OR

$BrCH_2CH_2Br$ Reason **unwanted termination**

6. 26.4g of bromine produced 9.23g of bromomethane.

a) Calculate the percentage yield.

Moles of bromine = 26.4/160= 0.165 mol

Moles of bromomethane = 9.23 / 95 = 0.0972mol

0.0973/0.165 x 100% = 58.9%

b) Calculate the atom economy for the reaction.

95/ (95 + 81) x 100% = 54.0 %

7. The bromomethane can be converted into methanol in one step.

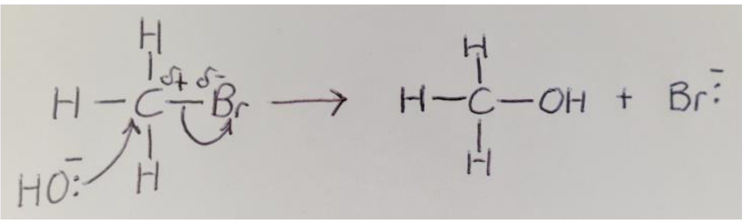
a) What is the name of this type of reaction? substitution

b) What are the reagents and conditions?

Reagents aqueous sodium hydroxide Conditions heat

c) What is the name of the mechanism? Nucleophilic substitution

d) Draw the mechanism for the reaction.



8. The methan**ol** can be oxidised readily to methan**al** (old name formaldehyde). In the lab this can be done using which common oxidising agent?

Potassium dichromate (VI) or $K_2Cr_2O_7$/ $Cr_2O_7^{-2}$

What other chemical is needed in the reaction?

Sulfuric acid

Would you select a **reflux** or a **distillation** set up for the reaction? Distillation (to prevent further oxidation)

Write an equation for this reaction using [O] to represent the oxidising agent.

$CH_3OH + [O] \rightarrow CH_2O + H_2O$

What colour change would you observe during the course of the reaction which would indicate the reaction was taking place?

Orange to green