Problem 3: Cleaning solutions

Curriculum links;
oxidation numbers, redox, halogens, moles, reacting masses

Practical skills;
collecting gas, accuracy

An ad agency is putting together an advertising campaign for a new bleach. They contact the students for help with determining the amount of NaOCl in various bleach samples (found by reacting a known quantity of each bleach with hydrogen peroxide and measuring the amount of oxygen produced). Using this information, the students are asked to determine if the new bleach is better value for money.

Extension discussion points:
- Should the hydrogen peroxide be added to the bleach or vice versa?
- Is the volume of gas generated the volume measured in the gas syringe / measuring cylinder?

Pre-Lab questions
(Remember to give full references for any information beyond A-level that you find out)

1. For each of the species below, indicate the oxidation state of the chlorine atom;

a) Cl^-	d) ClO_2^-	h) ClO_4^-
b) Cl_2	e) ClO_2	
c) ClO^-	f) ClO_3^-	

2. The active ingredient in household bleach is sodium chlorate(I), NaOCl, which is sometimes also known as sodium hypochlorite. This is formed when chlorine reacts with cold, dilute sodium hydroxide.

a) Write an equation for the reaction which occurs (HINT: NaOCl is not the only product).
b) This reaction is an example of a disproportionation reaction. Explain why.

3. Sodium chlorate is such a strong oxidising agent that it will oxidise hydrogen peroxide. In this process the chlorate(I) anion, ClO^- is reduced to a chloride anion and the hydrogen peroxide is oxidised to oxygen gas. The sodium ion is a spectator ion in the reaction.

a) Write two half equations for the reduction and oxidation processes respectively and combine to give a full redox equation for the reaction occurring.
b) A student reacts 20.0 cm^3 of bleach with an excess of hydrogen peroxide and measures the volume of oxygen produced. According to the label, the bleach contains 5% by volume of NaOCl (molar mass 74.5 g mol^{-1}).

i. What volume of NaOCl is present in the 20.0 cm^3 solution of bleach?
ii. If NaOCl has a density of 1.27 g cm^{-3}, what is the mass of sodium chlorate used in the reaction? How many moles of sodium chlorate(I) is this?

iii. The student reacts the bleach solution with an excess of H_2O_2. What is the minimum volume of a 1.67 mol dm^{-3} (often labelled *20 vol*) solution of hydrogen peroxide that the student must have used?

iv. Assuming the sodium chlorate is the limiting reactant and the reaction is run at room temperature and pressure, what volume of oxygen gas will be produced?

Billion Dollar Ad Agency, London

Dear team,

We are delighted to announce our recent success in securing the contract to advertise the brand new bleach, Best Bleach, designed by The Chemical Cleaning Company. Our job now is to come up with the most amazing advertising campaign to showcase its phenomenal bleaching ability.

In order to create the finest ad campaign for Best Bleach, we need to compare the concentration of the active bleaching agent in Best Bleach with that of the current brand leaders, Domestos and Milton solution. To satisfy the Advertising Standards Agency we need to know **the concentrations of sodium chlorate(I) in each of the bleaches given in g dm^{-3}** to the nearest whole gram. However, in these increasingly tight economic times we feel the **cost per gram** of sodium chlorate(I) present in each bleach will provide a direct and more understandable comparison for people doing housework across the country. At the time of writing, the costs of the Bleaches are as shown;

Domestos Original Bleach £1.12 for 750 mL
Milton Sterilising Fluid £2.39 for 1000 mL
Best Bleach 99p for 1 L

There is a tight deadline for the ad campaign. We need this data fast but it must also be accurate and able to stand up to the considerable scrutiny of the Advertising Standards Agency. A full report detailing all experimental procedures with accurate and valid experiment results is essential. You can assume that the concentration of sodium chlorate(I) in each bleach is not more than 5% by volume.

We look forward to receiving the results of your work.
Many thanks,