Problem 3: Cleaning Solutions

Teacher and Technician Pack

Pre-Lab answers

1.

a) Cl^- oxid^n state -1	d) ClO_2^- oxid^n state +3	h) ClO_4^- oxid^n state +7
b) Cl_2 oxid^n state 0	e) ClO_2 oxid^n state +4	
c) ClO^- oxid^n state +1	f) ClO_3^- oxid^n state +5	

2. a) Cl_2 (g) + 2 NaOH (aq) → NaOCl (aq) + NaCl (aq) + H_2O (l)
   b) 0 +1 -1 oxid^n states
   Cl_2 (g) + 2 NaOH (aq) → NaOCl (aq) + NaCl (aq) + H_2O (l)

In this reaction, the oxidation state of the gaseous Cl_2 both increases from 0 to +1 and decreases from 0 to -1. The chlorine is simultaneously oxidised and reduced. This type of redox reaction, in which a single substance is simultaneously oxidised and reduced is called a disproportionation reaction.

3. Reduction: $2e^- + 2H^+ + OCl^- \rightarrow Cl^- + H_2O$
   Oxidation: $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$
   Redox: $OCl^- + H_2O_2 \rightarrow Cl^- + H_2O + O_2$

   b) i. 5% of 20.0 cm^3 = 1.0 cm^3

ii. density = mass / volume ∴ mass = density × volume
mass of NaOCl in 1.0 cm^3 = 1.27 g cm^{-3} × 1.0 cm^3 = **1.27 g**
moles = mass / molar mass = 1.27 g / 74.5 g mol^{-1} = **0.017 moles**

iii. 1 equiv of NaOCl reacts with 1 equiv of H_2O_2. Therefore minimum no. of moles of H_2O_2 needed for the reaction = 0.017 moles.

conc = moles / volume ∴ volume = moles / conc
∴ minimum volume of H_2O_2 needed = 0.017 moles / 1.67 mol dm^{-3} = 0.010 dm^3
= 0.010 dm^3 or 10 cm^3

iv. 1 mole of NaOCl produces 1 mole of O_2. Therefore the no. of moles of O_2 produced is 0.017 moles.
1 mole of gas at rtp has a volume of 24.0 dm^3. Hence, volume of O_2 produced = 24.0 dm^3 × 0.017 moles = 0.410 dm^3 or 410 cm^3

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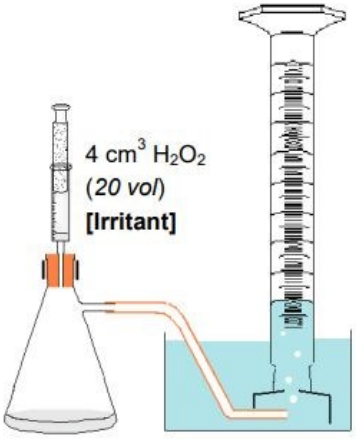
Proposed method



Using the pre-lab questions, students recognise that by reacting each of the bleaches with an excess of H_2O_2 and measuring the volume of O_2 produced, the concentration of NaOCl in each bleach can be determined.

3-5% bleach solutions and 20 *vol* H_2O_2 solution **cause serious eye and skin irritation**. Students must wear eye protection. Consider also providing the students with disposable chemical resistant gloves.

Using Q3 from the pre-lab questions, students decide upon a suitable scale; 4.0 cm^3 bleach* reacted with greater than 2 cm^3 of 20 *vol* H_2O_2

Students complete the experiment for each of the bleaches (with repeats) and measure the volume of oxygen generated. Calculations reveal for each bleach;

i. the concentration of NaOCl in g dm^{-3}

ii. the cost per gram of NaOCl

Bleach	Vol of water displaced / cm^3 (average of 3 runs)	Volume of O_2 generated / cm^3
Milton	30.5	25.5
Domestos	67.5	62.5
Best	53.0	48.0

4 cm^3 of Domestos produced 62.5 cm^3 of O_2 gas

∴ no. of moles of O_2 gas‡ = 62.5 cm^3 / 24000 $cm^3 mol^{-1}$

= 2.60×10^{-3} moles

∴ no. of moles of NaOCl in 4 cm^3 of Domestos = 2.60×10^{-3} moles

∴ mass of NaOCl in 4 cm^3 of Domestos;

2.60×10^{-3} moles × 74.5 g mol^{-1} = 0.194 g

*∴ **conc of NaOCl in Domestos** = $\frac{0.194\ g}{4\ cm^3} \times 1000\ cm^3\ dm^{-3}$ = **48.5 g dm^{-3}***

1 bottle of Domestos contains 48.5 g dm^{-3} × 0.75 dm^3 = 36.4 g of NaOCl

*∴ **cost per g of NaOCl in Domestos** = 112 p / 36.4 g = **3.08 pence g^{-1}***

Bleach	Concentration of NaOCl / g dm^{-3}	Cost of NaOCl / pence g^{-1}
Milton	20	12
Domestos	45	3.3
Best	35	2.8

* If the bleach is thick is may be necessary to dilute with water to aid the mixing process.

‡ The students may also wish to record the room temperature and use PV=nRT to calculate the no. of moles of gas produced

Conclusion

Best Bleach is the best value for money

Equipment list

Each group will need;

Chemicals;

- 20 cm^3 of each of three different bleaches. These can be the actual brands or solutions of sodium hypochlorite diluted to appropriate strengths. If possible aim for a thin bleach as with the thicker bleaches mixing is more difficult. Suitable bleaches would be;
    - Domestos original (sodium hypochlorite concentration = 4.5 g per 100 g) **[Irritant]**
    - Milton sterilising fluid (sodium hypochlorite concentration = 2 g per 100 g) **[Irritant]**
    - A 3.5 w/w solution of sodium hypochlorite (3.5 g of sodium hypochlorite made up to 100 g with water) labelled “Best Bleach” **[Irritant]**
    - 60 cm^3 of 20 vol hydrogen peroxide **[Irritant]**

Laboratory equipment – 2 sets per group;

- 1 × 5 cm^3 plastic syringe for the measurement and delivery of the hydrogen peroxide
- 1 × 5 cm^3 plastic syringe for the measurement of the bleach solution
- Rubber bung to fit a 100 cm^3 Büchner flask with one hole of an appropriate size to tightly fit the neck of the
- plastic syringe used for delivery of the hydrogen peroxide
- 100 cm^3 Büchner flask
- Delivery tubing to fit the side arm of the Büchner flask
- 100 cm^3 measuring cylinder
- Water trough
- Bee hive
- Access to deionised or distilled water
- Clamp and stand

NOTE The equipment provided must allow the students to add the hydrogen peroxide solution to the bleach in a sealed environment (the reaction is too quick to mix and then quickly bung the flask). This can either be achieved by the method illustrated or by using a pressure equalised dropping funnel. The equipment list will therefore need to be modified to fit the equipment available.

Health and safety note

3-5% bleach solutions and 20 vol hydrogen peroxide solution are **irritating to the eyes and skin**. Students must wear eye protection throughout. Consider also providing the students with disposable, chemical resistant gloves.

The concentrations of bleach used in this experiment will remove colour from clothing. Therefore, the students need to take special care to protect their clothing from bleach spills.