Learn Chemistry

Problem Based Practical Activities

Problem 3: Cleaning solutions

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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?

Problem 3: Cleaning solutions

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?

Problem 3: Cleaning Solutions

Introduction

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. In order 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 that the **cost per gram** of sodium chlorate(I) present in each bleach will provide an easy, direct and more understandable comparison for housewives 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,

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) $Cl_2\ (g) + 2\ NaOH\ (aq) \rightarrow NaOCl\ (aq) + NaCl\ (aq) + H_2O\ (l)$

b) *0 +1 -1 oxid^n states*

$Cl_2\ (g) + 2\ NaOH\ (aq) \rightarrow NaOCl\ (aq) + NaCl\ (aq) + H_2O\ (l)$

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. a) 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
= <u>0.010 dm^3 or 10 cm^3</u>

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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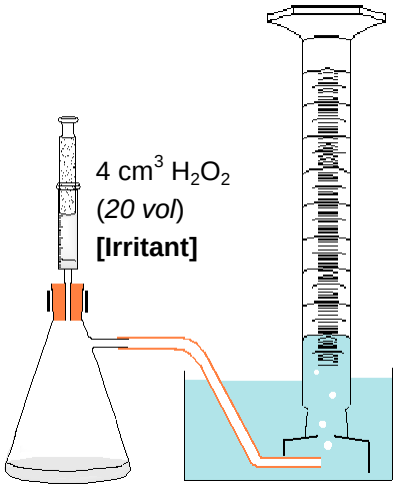
Proposed method



4 cm^3 bleach **[Irritant]**

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 cm³ of Domestos produced 62.5 cm³ of O_2 gas

∴ no. of moles of O_2 gas‡ = 62.5 cm³ / 24000 cm³ mol⁻¹

= 2.60 × 10⁻³ moles

∴ no. of moles of NaOCl in 4 cm³ of Domestos = 2.60 × 10⁻³ moles

∴ mass of NaOCl in 4 cm³ of Domestos ;

2.60 × 10⁻³ moles × 74.5 g mol⁻¹ = 0.194 g

*∴ **conc of NaOCl in Domestos** = $\frac{0.194\ g}{4\ cm^3}$ × 1000 cm³ dm⁻³ = **48.5 g dm⁻³***

1 bottle of Domestos contains 48.5 g dm⁻³ × 0.75 dm³ = 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

Teacher and Technician Pack

Equipment list

See the **Health and safety guidance** section in the **Introduction** for more general information on risk assessments and a key to the health and safety symbols used.

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.