The 'breathalyser' reaction

Learning objectives

1 Observe an application of the oxidation of primary alcohols using acidified potassium dichromate solution.

2 Recall the colour change of the chromium-containing species in the 'breathalyser' reaction and the products of oxidation of primary alcohols.

3 Understand that you can use the reaction as an analytical test to identify (primary or secondary) alcohols.

4 Write redox equations and review transition elements' properties.

Introduction

Primary alcohols can be oxidised by the oxidising agent acidified potassium dichromate ($K_2Cr_2O_7$). In this demonstration you will see how to use the 'breathalyser' reaction to test for the presence of primary (or secondary) alcohols. Watch the teacher demonstration then answer the questions.

Find more details on how chemists use infrared spectrometry to detect alcohol in drivers' breath on page 82 of *Modern chemical techniques: infrared spectroscopy*, available from rsc.li/3SOErUL.

Questions

1. The side-arm boiling tube contains acidified potassium dichromate solution.

(a) State the colour of the acidified potassium dichromate reagent before any ethanol is 'blown' through the tube.
(b) Which of the ions present is responsible for that colour? (The ions present are H^+, SO_4^{2-}, K^+ and $Cr_2O_7^{2-}$.)
(c) What is the oxidation state of the chromium in acidified potassium dichromate, $K_2Cr_2O_7$?

2. The oxidising agent, when completely reacted, changes to its final colour.

(a) State the final colour of the oxidising agent.
(b) State the formula of the ion responsible for the final colour.
(c) State the oxidation state of the chromium in this species.

3. The colour of the oxidising agent first changes to brown. Suggest an explanation for the brown colour.

4. The ethanol blown through the boiling tube is oxidised.

(a) Draw the displayed formula of the product of partial oxidation of ethanol.
(b) Name this product.
(c) Draw the displayed formula of the product of full oxidation of ethanol.
(d) Name this product.

5. Chemists use the reaction with acidified potassium dichromate ($K_2Cr_2O_7$) as a test for ethanol.

(a) Which types of alcohols give a positive result?
(b) Name one type of organic compound which would also give a positive test with acidified potassium dichromate other than alcohols.

6. This reaction illustrates two important properties of transition metals. State them.

7. We often use $[O]$ to represent an oxidising agent in equations of these oxidation reactions. You can consider this as the equivalent of one oxygen atom in oxidation state zero.

(a) Balance the equation: $C_2H_5OH + [O] \rightarrow CH_3COOH + H_2O$
(b) Balance the equation: $C_2H_5OH + [O] \rightarrow CH_3CHO + H_2O$

8. There is a type of early breathalyser, similar to this demonstration, that depends on a person blowing into a bag until it is full. Explain why the test is unreliable if you do not fill the air bag?

Challenge

9. Considering the change in oxidation state of the oxygen, finish off the half-equation for the reduction: $[O] + \quad + \quad \rightarrow H_2O$

10. By considering your answers to questions 9 and 7(b), deduce the number of electrons and H^+ ions in the oxidation half-equation: $C_2H_5OH \rightarrow CH_3CHO + \quad +$

11. Write a half-equation for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}.

12. By considering your answers to questions 10 and 11, balance the equation:
$C_2H_5OH + Cr_2O_7^{2-} + H^+ \rightarrow CH_3CHO + Cr^{3+} + H_2O$

13. Evaluate the relative merits of the type of equation used in question 7 compared to that constructed in question 12.