The ‘breathalyser’ reaction

Demonstration

In this quick demonstration of the reaction between **ethanol** and **potassium dichromate(VI)**, ethanol vapour is passed through a U-tube packed with potassium dichromate crystals, moistened with dilute sulfuric acid, to produce a visible change from the orange of chromium(VI), through brown, to the green of chromium(III). This was the reaction used in earlier forms of 'breathalyser'.

Lesson organisation

This is a teacher demonstration which takes 5 minutes to perform, or longer if a complete change of colour from orange to green is desired.

The acidified potassium dichromate(VI) mixture must be made up and placed in the U-tube beforehand by the teacher or technician, wearing suitable protective clothing.

Apparatus	Chemicals
Eye protection. Wear goggles for preparing and handling the acidified dichromate(VI) mixture. **Disposable nitrile gloves (for handling potassium dichromate(VI) crystals)** **Beaker (100 cm^3)** **Conical flask (250 cm^3), 2** **Rubber bung, 2-hole, to fit flask** **U-tube, approx. 10 cm tall, with or without side-arms** **Rubber bungs, 2, to fit the ends of the U-tube (Note 1)** **Glass tubing, 4 lengths (Note 2)** **Rubber bung, 1-hole, large** **Plastic sandwich bag, about 20 x 15 cm** **Spatula** **Glass stirring rod** **Rubber tubing, short lengths - to make connections** **Sterile mouthpieces – short lengths of glass tubing to attach to the inlet tube** **Plastic cable tie, adhesive tape or a length of thread.**	Ethanol (IDA, Industrial Denatured Alcohol) (HIGHLY FLAMMABLE, HARMFUL), about 100 cm^3 Ethanal (acetaldehyde) (EXTREMELY FLAMMABLE, HARMFUL), small sample for testing odour Ethanoic acid solution (acetic acid), 1 - 2 M (IRRITANT), small sample for testing odour For the acidified dichromate(VI) mixture **(Note 3):** Potassium dichromate(VI) crystals (OXIDISING, VERY TOXIC, DANGEROUS FOR THE ENVIRONMENT), about 30 g Dilute sulfuric acid, 2 M (CORROSIVE), 3 cm^3 **Refer to Health & Safety and Technical notes section below for additional information.**

Filter pump

Health &Safety and Technical notes

Read our standard health &safety guidance

Eye protection. Wear goggles and disposable nitrile gloves for preparing and handling the acidified dichromate(VI) mixture.

Ethanol (IDA, Industrial Denatured Alcohol), $C_2H_5OH(l)$, (HIGHLY FLAMMABLE, HARMFUL) - see CLEAPSS Hazcard.

Ethanal (acetaldehyde), $CH_3CHO(l)$, (EXTREMELY FLAMMABLE, HARMFUL) - see CLEAPSS Hazcard.

Ethanoic acid solution (acetic acid), $CH_3COOH(aq)$, (IRRITANT) - see CLEAPSS Hazcard and CLEAPSS Recipe Book.

Potassium dichromate(VI), $K_2Cr_2O_7(s)$, (OXIDISING, VERY TOXIC, DANGEROUS FOR THE ENVIRONMENT) - see CLEAPSS Hazcard.

Dilute sulfuric acid, $H_2SO_4(aq)$ (CORROSIVE) - see CLEAPSS Hazcard and CLEAPSS Recipe Book.

1 The bungs must be solid if the U-tube has side-arms, or have 1 hole if the U-tube has no side-arms.

2 Three of the lengths of glass tubing must be bent as shown in the diagram if the U-tube has no side-arms. If it has side-arms then the U-tube can be attached to the glass tubes from the flask and the bag by means of rubber tubing.

3 The acidified dichromate mixture is prepared as follows:

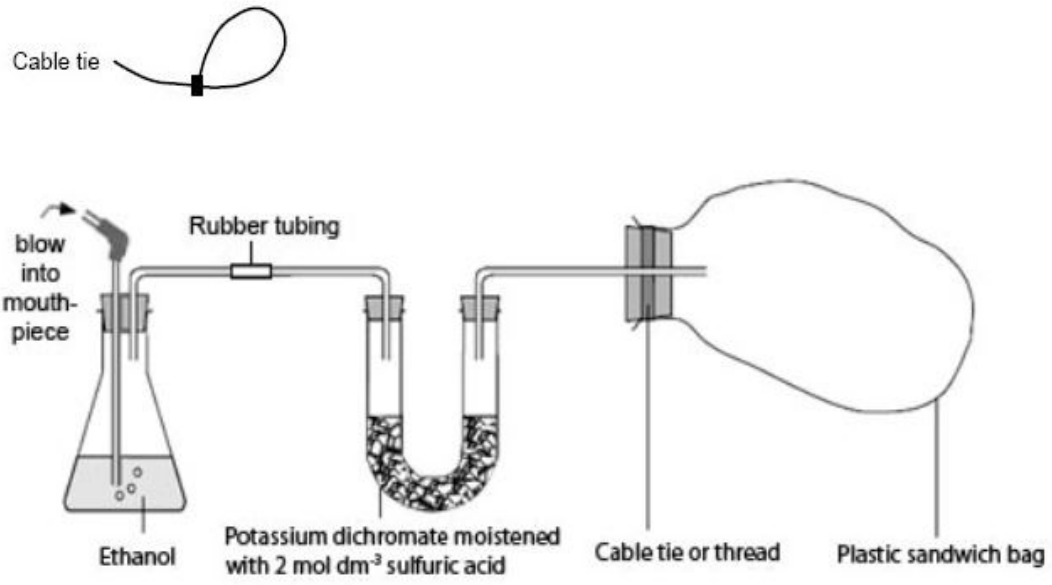
Wearing disposable nitrile gloves and eye protection, weigh out into a beaker sufficient potassium dichromate crystals to half-fill the U-tube (about 30 g).

Add dilute sulfuric acid (2 M) to the crystals in the beaker, in the ratio 1 cm^3 of acid to 10 g of dichromate. Mix thoroughly, using a glass rod or spatula, to produce moistened crystals of potassium dichromate.

Half-fill the U-tube with the crystals, tapping the tube gently to pack them down.

Place ethanol in the conical flask to such a depth that the longer of the glass tubes is below the surface of the ethanol and the shorter one is not. Fit the longer tube with a sterile mouthpiece consisting of a short length of clean glass tubing attached by means of rubber tubing.

Attach a plastic sandwich bag to the large, one-holed, rubber bung by gathering the neck of the bag around the bung and binding it tightly with a cable tie or using thread.



Procedure

a Ensure the plastic bag is deflated at the start. Before connecting the flask to the U-tube, blow air by mouth through the ethanol so that the air in the flask is saturated with ethanol vapour.

b Connect the conical flask, U-tube and plastic bag as shown in the diagram, and place a white background behind to make the colour changes easier to see. A sample of unreacted potassium dichromate(VI) is useful for comparison as the reaction proceeds.

c Blow gently into the ethanol-containing flask so that the air bubbles steadily through the ethanol, passes over the acidified potassium dichromate(VI), and into the plastic bag.

d The dichromate(VI) crystals in the arm of the U-tube nearest the ethanol will turn brown. This is caused by a mixture of unreacted orange crystals and a green chromium(III) compound, a product of the reaction. The quantities of reagents are such that one bagful of air will not be sufficient to complete the reaction.

e To produce a complete change from orange to green, remove the bag, and connect a filter pump in its place so that air containing ethanol vapour is drawn slowly over the crystals for several minutes, until sufficient green colour is visible.

f Disconnect the U-tube and remove the stoppers. Pass it round the class for the students to smell the products of the reaction. Compare with the smells of small samples of ethanal and ethanoic acid solution, both possible products of the reaction, by passing around specimen tubes containing a wooden splint or filter paper strip dipped into the relevant liquid.

Teaching notes

The reaction could also be demonstrated in a test-tube before or after the ‘breathalyser’ demonstration. Advanced students may carry out the test-tube reaction themselves as part of their study of the properties of alcohols.

Depending on the wider context of the lesson, this could be a suitable opportunity to discuss the dangers of drinking and driving, although modern 'breathalysers' use electronic methods to detect and measure alcohol concentration.

The ionic equations for the reactions occurring are:

(i) for oxidation of ethanol to ethanal:

$Cr_2O_7^{2-} + 3C_2H_5OH + 8H^+ \rightarrow 2Cr^{3+} + 3CH_3CHO + 7H_2O$

(ii) for oxidation of ethanol to ethanoic acid:

$2Cr_2O_7^{2-} + 3C_2H_5OH + 16H^+ \rightarrow 4Cr^{3+} + 3CH_3COOH + 11H_2O$

Health &Safety checked, 2016

Credits

This Practical Chemistry resource was developed by the Nuffield Foundation and the Royal Society of Chemistry.

Websites

How stuff works - this site discusses the chemistry of the chemical breathalyser as well as more modern types.

Wikipedia - for a more general discussion, probably more for teacher background, of breath testing for alcohol, from the history to the various methods and their problems.

Page last updated October 2015