A microscale study of gaseous diffusion

Topic
Diffusion as evidence for particles, diffusion equations, gases, transition elements (redox reactions, catalysis and variable oxidation states).

Timing
30–40 min.

Description
This experiment looks at the spread of ammonia and chlorine gases as a result of their interaction with copper(II) sulphate and potassium iodide/starch solutions. The experiment is done using drops of solutions placed on a clear plastic sheet with the top of a well-plate as a lid. The experiment is suitable for various levels with differing degrees of interpretation.

Apparatus (per group)
- One student worksheet
- One clear plastic sheet (eg ohp sheet)
- Two well-plate lids (24 well size, eg Sigma ref: M 9655)
- Two plastic pipettes
- Magnifying glass.

Chemicals (per group)
Solutions contained in plastic pipettes, see 'Apparatus and techniques for microscale chemistry' handout.
- Concentrated ammonia solution
- Potassium iodide 0.2 mol dm⁻³
- Hydrochloric acid 1 mol dm⁻³
- Copper(II) sulphate 0.5 mol dm⁻³
- Starch solution
- Bleach.

Observations
In the ammonia experiment the drops of copper(II) sulphate solution first turn opaque blue due to the formation of copper(II) hydroxide and then gradually develop dark blue blotches and streaks as the tetra-amminocopper(II) ion is formed. The colour changes and patterns are seen using a magnifying glass. The fact that patterns are seen at all and that the colour changes are not uniform suggests movement within the drops.

In the chlorine experiment the liberated iodine gives a blue-black colour with the starch. In both experiments there is a gradation of colour change which depends on the rate of diffusion of the gas. It
might be possible to compare the rate of diffusion of these two gases. Ammonia with a relative molecular mass of 17 should be faster than chlorine with a relative molecular mass of 71. The rates of evaporation of ammonia from concentrated ammonia solution and the rate of the generation of chlorine from the reaction between bleach and hydrochloric acid may be different. Moreover, the sensitivities of the respective drops to show colour changes on reaction with the gases may also be different.

Students may also be encouraged to develop their understanding of the properties of gases from this experiment. For example, the large difference in relative molecular mass of ammonia and chlorine manifests itself in differences in rates of diffusion by combining Avogadro’s Hypothesis (equal volumes of all gases contain, under equal conditions, equal numbers of molecules) and Graham’s Law of Gaseous Diffusion (the rate of diffusion of a gas is inversely proportional to the square root of its density).

In the chlorine experiment, the liberated iodine tends to stain the plastic sheet if left in contact with it for a while. Since the amount of iodine liberated depends on the amount of chlorine present a note of the rate of chlorine diffusion is recorded on the plastic sheet. This could be shown on an overhead projector or displayed on a wall.

Reference

Health & Safety

Students must wear suitable eye protection (Splash resistant goggles to BS EN166 3).

Ammonia solution, concentrated NH₃ (aq) is CORROSIVE.

Potassium iodide, 0.2 mol dm⁻³, KI (aq) is low hazard.

Hydrochloric acid, 1 mol dm⁻³ HCl (aq), is low hazard.

Copper(II) sulphate solution, 0.2 mol dm⁻³, CuSO₄ (aq) causes eye damage and is toxic to aquatic life.

Household bleach solutions (containing sodium chlorate(I) / sodium hypochlorite) sold for the domestic market may be corrosive but is commonly more dilute and irritant. Check the label. Even quite dilute bleach is irritant if more than 0.15 M NaOCl. Some bleaches also contain detergents and thickening agents, which may cause excessive frothing in this experiment. Note that nowadays some commercially available bleaches do not contain any chlorine and are based on peroxy-compounds. They should not be used here.

Credits
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Health & safety checked May 2018

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