

Diffusion of gases on a microscale – teacher notes

This experiment looks at the spread of ammonia and chlorine gases as a result of their interaction with copper(II) sulfate 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. It is suitable for various levels with differing degrees of interpretation.

Topic

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

Timing

30–40 minutes

Equipment

Apparatus

- Eye protection
- Student worksheet
- Clear plastic sheet (eg ohp sheet)
- Well-plate lids (24 well size, eg Sigma ref: M 9655), x2
- Plastic pipettes, x2
- Magnifying glass

Chemicals

Solutions should be contained in plastic pipettes. See the accompanying guidance on apparatus and techniques for microscale chemistry (<https://rsc.li/3km0RMc>), which includes instructions for preparing a variety of solutions.

- Concentrated ammonia solution
- Potassium iodide, 0.2 mol dm^{-3}
- Hydrochloric acid, 1 mol dm^{-3}
- Copper(II) sulfate, 0.5 mol dm^{-3}
- Starch solution
- Bleach

Procedure

1. Cover the worksheet with a clear plastic sheet.
2. Place two drops of copper(II) sulfate solution in each square (except the one with the circle) of the left hand grid (the one labelled ammonia).

3. Place one drop of potassium iodide solution in each square (except the one with the circle) of the right hand grid (labelled chlorine). Add one drop of starch solution to each drop.
4. Cut the bottom off two plastic pipettes to make a small vessel and place each on the square with the circle.
5. Carefully put four drops of ammonia in the vessel in the 'ammonia' grid and quickly place a well-plate lid over the grid.
6. Carefully put two drops of bleach and two drops of hydrochloric acid in the vessel in the 'chlorine' grid and quickly place a well-plate lid over the grid.
7. Record all your observations over the next 20 minutes and give explanations.

Teaching notes and expected observations

In the ammonia experiment the drops of copper(II) sulfate solution first turn opaque blue due to the formation of copper(II) hydroxide and then gradually develop dark blue blotches and streaks as the tetraamminecopper(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 rate 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.

Health, safety and technical notes

- Read our standard health and safety guidance (<https://rsc.li/3B1z3CZ>).
- Wear eye protection throughout (splash resistant goggles to BS EN166 3).
- Ammonia solution, concentrated $\text{NH}_3(\text{aq})$ is CORROSIVE. See CLEAPSS Hazcard HC006 and CLEAPSS Recipe Book RB006.

- Potassium iodide, KI(aq), 0.2 mol dm⁻³ is low hazard. See CLEAPSS Hazcard HC047b and CLEAPSS Recipe Book RB072.
- Hydrochloric acid, HCl(aq), 1 mol dm⁻³ is low hazard. See CLEAPSS Hazcard HC047a and CLEAPSS Recipe Book RB043.
- Copper(II) sulfate solution, CuSO₄(aq), 0.2 mol dm⁻³ causes eye damage and is toxic to aquatic life. See CLEAPSS Hazcard HC027c and CLEAPSS Recipe Book RB031.
- 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. See CLEAPSS Hazcard HC089.