TUNNELWORKS
A2 CHEMISTRY
TEACHERS' NOTES

About this lesson

This single or double lesson (see below) helps students explore stoichiometry and titrations using a real-world example of testing for dissolved oxygen in water using the Winkler test. Students must 'track' how one mole of oxygen is represented within each stage of the test's reactions to identify how many moles of sodium thiosulphate represent one mole of oxygen, in the final titration. Students then calculate the results of titrations using a range of Winkler test kits to find out which are suitably accurate, exploring how the choice of equipment, solutions and method all combine to deliver the resolving power (precision) of a titration.

Learning outcomes

Students can:

- Apply ideas of stoichiometry and conservation of mass
- Calculate the results of titrations
- Interpret data and other information to identify the features of a 'good' titration with sufficient resolving power or precision.

Curriculum links

A2 (A level) Chemistry

- Titrations, equations and formulae

What you will need

- A2 Chemistry presentation screens A1-6
- Student sheets 1 and 2
- Students will need calculators

Please allow time to show the introductory video at the start of the presentation.

Preparation

Students should already be familiar with titrations and will need to be able to complete equations for reactions using stoichiometry, applying ideas of conservation of mass.

Watch the introductory video if you are not familiar with the Thames Tideway Tunnel.
Review the delivery plan for the lesson (below), the overview of the Winkler Test reactions on student sheet 2, and student sheet 1. Consider appropriate differentiation for your class using the ideas after the delivery plan. Adjust the timings to suit your lesson length.

Single lesson: omit the exploration of each stage. Introduce the test and simply establish that 2 mol I_2 in the treated sample represents 1 mol O2 in the water, so 4 mol sodium thiosulphate represents 1 mol dissolved oxygen during the titration.

Double lesson: explore each stage of the reaction and challenge students to complete each reaction's equation.

A video explaining one commercial Winkler Test kit is available at http://www.youtube.com/watch?v=FKdzbgHaQQM and you may also want to show this to give students an idea of the kind of kit they are 'testing' using the data on student sheet 1.

Background information

The Thames Tideway Tunnel is a major new sewer that will help tackle the problem of sewage overflows from London's sewers and will protect the River Thames from increasing pollution for at least the next 100 years, enabling the UK to meet European Union environmental standards. The Tunnel will control the 34 most polluting combined sewer overflows (CSOs), as identified by the Environment Agency, which currently discharge untreated sewage directly into the River Thames after it rains.

The majority of London's sewers collect both sewage and rainwater and after heavy rainfall the volume flowing through the sewers is a lot higher than the system can take. The original Victorian system is designed to discharge this excess sewage directly into the River Thames through a series of combined sewer overflows (CSOs). The new Thames Tideway Tunnel will control the most polluting CSOs by capturing combined rainwater and sewage and allowing it to flow down a new tunnel before being pumped out for treatment at Beckton Sewage Treatment Works.

There are four dissolved oxygen standards set for the Tidal Thames summarised in the table below. (Broadly speaking, the Tidal Thames extends from Teddington Lock out into the Thames Estuary.)

Standard	Dissolved oxygen (DO) concentration threshold (mgl^{-1})	Tide Duration below this DO threshold (tides)	How often this may happen before the standard is failed (once every X years)
1	4	29	1
2	3	3	3
3	2	1	5
4	1.5	1	10

Computer modelling results show that the Tidal Thames today fails all of the DO standards that have been developed for the Tideway to ensure fish sustainability. Fish kill events will affect the sustainability of some key species, and the diversity of species that can inhabit the Thames Tideway is suppressed.

The Winkler test is one standard approach to measuring dissolved oxygen. The stages and reactants presented here are simplified and several components of a real kit have been omitted to concentrate on the essential process. Accurate testing using this method is dependent on good technique to prevent changes in dissolved oxygen once the sample has been collected. This entails completely filling then sealing the sample bottle, and adding the initial reactants to fix the dissolved oxygen in a way that doesn't introduce more oxygen into the sample. The YouTube video on the previous page helps explain this. A lot more information on the Winkler test is available on the Internet.

Delivery

Time (2x 60mins)	Teaching activity	Learning activity
10 mins	**Don't hand out Student sheet 2 yet.** **Starter:** Ask students to share their understanding of titrations – what they are for, how they should be carried out etc. See if students can suggest a real-world use for titrations. Introduce the scenario – that a titration forms the final stage in a test for dissolved oxygen in water. Discuss why this might be important.	Share prior learning about titrations and make real-world suggestions. Share ideas about the importance of dissolved oxygen for river life.
15 mins	**Whole-class:** Show the introductory video (link above) and Screen A1: to establish that the Thames Tideway Tunnel will help ensure the health of the River Thames by reducing sewage discharges into the river, which can greatly reduce dissolved oxygen levels (student sheet 1 has notes on this). Screen A2: Introduce the Winkler test and optionally watch the YouTube video (link above) to help students imagine what it involves. Explain that students must work out how 1 mol O_2 is represented by reactants / products at each stage so they can complete the titration calculation and interpret the result. *To simplify to a single lesson, skip stages 1 and 2 or review them very briefly.*	Watch video and discuss scenario. Review information about the Tunnel on student sheet 1. Watch video. It's helpful to identify that this uses a simple syringe, not a titration tube (which has greater precision).
15 mins	**Stage 1 – whole class + pairs/ individuals:** Screen A3: Establish that it's important to 'fix' the O_2 level in the sample and discuss why. Note that students aren't tracking oxygen itself, but the reactants / products that 'represent' it at each stage. Explore and complete the first equation.	Share ideas, eg that they don't want the sample to lose of absorb oxygen after it is taken. Can also share ideas on how to prevent this through filling the sample bottle completely, sealing, adding reactants via syringe etc.

	Explore and complete the second equation. Hint: the manganese is oxidised from a (II) to (IV) state. See if students can identify that the potassium iodide has not yet been involved in the process. Challenge students to identify what now 'represents' 1 mol O_2 (the manganese xyhydroxide) and how much (2 mol). Keep track of this.	In pairs complete equations. Identify that 2 mol manganese oxyhydroxide represent 1 mol O_2 in the next stage.
5 mins	**Stage 2 – whole class + pairs/ individuals:** Screen A4: Establish the formula for a sulphate ion and complete the first equation. See if students can identify that the manganese sulphate now 'represents' the O_2. Complete the second equation. Hint: the manganese is reduced from a (IV) to a (II) state. Challenge students to identify that 2 mol I_2 now 'represents' the 1 mol O_2 in the sample water. End of lesson 1.	Share ideas. In pairs complete equation. Identify manganese sulphate as the next 'representative' reactant. In pairs, complete equation. Identify 2 mol I2 as final 'representative' of the O_2. Share ideas on equipment, method etc. Identify starch as the correct indicator.
5 mins	**Starter:** Building on the lesson 1 starter, discuss what students might expect to do to complete an iodine - sodium thiosulphate titration using starch indicator.	In pairs complete titration reaction.
10 mins	**Stage 3 – whole class + pairs/ individuals:** Screen A5: Remind students that 2 mol I_2 now represents each mol O_2 dissolved in the sample. Complete the equation and establish that 4 mol thiosulphate will react in the titration for each mol O_2 dissolved in the water sample. Review all three stages using some or all of student sheet 2.	Can take turns to explain each stage in their own words.

10 mins	**Whole class:** Screen A6: Ask students to share how they would calculate the amount of dissolved O_2 in mg per litre using: - titration data (volume and concentration of thiosulphate) - ratio of thiosulphate to O_2 (4:1) - molar mass O_2 (32g) - sample bottle size (to scale up to a measure per litre) Complete a worked example: 9.5 ml 0.025M thiosulphate is used to titrate a 500ml sample of water taken after a sewage discharge. What is the dissolved oxygen level? ($3.8 mgl^{-1}$)	Share how to: - calculate mol of thiosulphate using volume and concentration - convert to mol of O_2 by dividing by four - convert to mass by multiplying by 32 - how to scale up to 1 litre depending on the sample size they have titrated.
25 mins	**Pairs / individuals:** Review the task on student sheet 1, noting that the titrations are done using a plastic syringe in the field, with 0.1ml accuracy, less than a lab titration. Help students as they calculate the dissolved oxygen levels using data from each kit.	In pairs or as whole group calculate this example. Complete the task, calculating the moles of thiosulphate, the O_2 this represents and the dissolved oxygen level this indicates per litre.
5 mins	**Whole class:** Discuss the results and what they tell students about each kit. Look in particular at the sample size and thiosulphate concentrations and elicit how these combine to give the 'resolving power' of each kit, eg the precision to which it can measure dissolved oxygen in the sample.	Identify that stronger thiosulphate solutions and smaller samples each reduce the resolving power (precision) of the test, given that the syringe will only allow them 0.1ml accuracy. Students can compare the mass of dissolved O_2 each ml indicated in each kit (from $0.2 mgl^{-1}$ (good) to $0.8 mgl^{-1}$ (poor).
5 mins	Plenary: Identify that the best kits use weaker concentrations and larger sample sizes, leading to greater precision. Help students identify that titrations need to be designed to match the sensitivity required.	Share ideas in discussion.

Answers

Worked example:

(9.5ml / 1000ml) x 0.025M x 0.25 x 32gmol^{-1} x (1000ml / 500ml) = 3.80 mg O_2l^{-1}

Kits A and C are reliable (within 0.1mg O_2l^{-1}).

A (worked answer)

(11.7ml / 1000ml) x 0.025M x 0.25 x 32gmol^{-1} x (1000ml / 300ml) = 7.80 mg O_2l^{-1}

B = 7.68 mg O_2l^{-1}

C = 7.80 mg O_2l^{-1}

D = 8.10 mg O_2l^{-1}

E = 8.00 mg O_2l^{-1}

Differentiation

Easier	Harder
Talk briefly through each stage, or simply skip stages and establish that after 'fixing' the dissolved oxygen, 4 moles thiosulphate will react with 2 moles iodine, which represents 1 mole dissolved oxygen in the sample. Complete kit A together as another example.	Challenge students to complete equations for themselves and work more independently.

Extension / Follow-up ideas

Commercial dissolved oxygen test kits are available, which enable 40 – 110 tests. Use these to sample local water *(NB ensure you complete a suitable risk assessment for taking water samples from any body of water)*.

Set up test iodine titrations using different concentrations of sodium thiosulphate and different volumes of iodine solution. Challenge students to identify the titration with the greatest precision, explaining their choice.

With the help of your lab technicians, prepare the reagents for students to complete a Winkler test. *(NB ensure you complete a suitable risk assessment for the reagents)*.

Reagent and testing instructions from the University of Illinois:
http://gk12.web.cs.illinois.edu/store_folder/Winkler_Method.pdf