# TUNNELWORKS
# AS CHEMISTRY
# TEACHERS' NOTES

## About this lesson

This lesson gives students practice in calculating the enthalpy change for exothermic reactions using a real-world example and sample experimental data. Students can discuss experimental technique and the real world implications of a reaction being exothermic.

## Learning outcomes

**Students can:**
- Identify the energy pathway diagram for an exothermic reaction
- Work with atomic masses, specific heat capacity and temperature data
- Calculate standard enthalpy change of reaction for the amount for two reaction equations.

## Curriculum links

**AS chemistry (all specifications)**
- Energetics – enthalpy changes

## What you will need

- AS Chemistry presentation screens AS1-4
- Student sheet
- 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 enthalpy.

Watch the introductory video if you are not familiar with the Thames Tideway Tunnel.
Review the delivery plan for the lesson (below) and the student sheet and consider appropriate differentiation for your class. Adjust the timings to suit your lesson length or to extend to a double lesson.

## 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 Tunnel will be lined with thousands of concrete segments. Concrete is a mixture of cement and aggregates, including sand and gravel. The cement acts as a binder.

Cement is a mixture of substances as listed on the student sheet. The complete chemistry of cement is complex and this lesson uses a simplified approach that focuses only on two of the reactions, those of the tri- and dicalcium silicates. These make up the bulk of the cement. The tricalcium silicates, which hydrate more quickly, provide the concrete's early strength during the first few days, and the dicalcium silicates, which hydrate more slowly, then provide most of its long-term strength. This strength comes from the hydration of these silicates to form a crystal matrix of calcium silicate hydrate along with calcium hydroxide. The hydration reactions are exothermic and continue for an extended period deep within the concrete, meaning that its strength will continue to increase over time as long as water is available for hydration to happen.

The hydration reactions seem complex but are simpler than they look. Point out that the dots in the calcium silicate hydrate show that it exists as a crystal matrix. When working out the equation for the tricalcium silicate reaction the only difference in physical products is in the amount of calcium hydroxide produced. Students could use this to predict that the tricalcium silicate reaction is more exothermic than that for dicalcium silicate.

## Delivery

| Time (60mins) | Teaching activity | Learning activity |
|---|---|---|
| **10 mins** | **Starter:** Review students' understanding of enthalpy.<br>Lead a brief discussion of how students might measure a change in enthalpy experimentally. | Students recall and share their ideas. |
| | Screen AS 1: Introduce the scenario, showing the introductory video online if you wish. | Students watch video and review slide content. |
| | Discuss what students know already about concrete and cement (you may want to point out that a form of cement was used by the Romans – it's not a modern material). | Share ideas. |
| **15 mins** | **Whole class:** Discuss inorganic hydration reactions and establish that water is being added to the crystal structure of a mineral. Screen AS 2 | Students could share their ideas about what is actually happening to the water as concrete 'dries' (it's absorbed into the crystal structures that form). |
| | Ask students to sketch the energy pathway based on this information, then reveal the completed diagram. | Students use knowledge of valence to write formulae. |
| | If you wish, help students identify the chemical formula for tri-and dicalcium silicate. | Review reaction in equation form. |
| | Screen AS 3: Show the formula for the dicalcium silicate reaction. Identify the calcium silicate hydrate crystal formula and establish that this is identical in both reactions. (Ask students why both silicates are needed – answer in background information, above.) | |
| **20 mins** | **Pairs or individuals:** Screen AS 3 cont'd: Challenge students to write the formula for the tricalcium silicate reaction. Ask students if they think this will be more or less exothermic, and why. | Generate equation for tricalcium silicate reaction based on the dicalcium silicate reaction. |

| | | |
|---|---|---|
| **5 mins** | **Whole class:** Screen AS 4: Explain that students are going to calculate the enthalpy of reaction for each hydration reaction. Establish that any value for this only has meaning for the specific equation used.<br><br>Review the student sheet. Help students identify steps they must complete:<br><br>*1. Calculate molar mass of each silicate*<br>*2. Calculate no. moles added*<br>*3. Calculate change in temperature*<br>*4. Calculate energy given off to produce this change in temperature* | Identify key steps and calculations, and how they will use each piece of data.<br><br>Students calculate enthalpy change for reactions as shown.<br>Share answers. |
| **5 mins** | **Pairs or individuals:** Help students as they calculate the enthalpy change for each reaction.<br><br>**Whole class:** Review calculation steps and share answers.<br><br>**Plenary:** Discuss why it might be important to know the enthalpy change of reactions that occur in practical applications like this. For example, when casting large concrete segments, what safety or process issues might arise? | Share ideas, eg risk of burns, materials used for moulds, personal protection required etc. |

## Answers

There are 2 mol $Ca_2SiO_4$ and the average temperature rise is 11.7 $^{o}$C.

11.7 x 1.2 x 4181 = 58.7kJ heat for the reaction as stated.

There are 2 mol $Ca_3SiO_5$ and the average temperature rise is 34.58 $^{o}$C.

34.58 x 1.2 x 4181 = 173.5kJ heat for the reaction as stated.

## Differentiation

| Easier | Harder |
|---|---|
| Just focus on one reaction.<br><br>Provide molar masses:<br>Tricalcium silicate: 228g<br>Dicalcium silicate: 172g | Cement blends can include 45-75 tricalcium silicate and 7-30% dicalcium silicate. Ask students to calculate the heat output of different blends of di- and tricalcium silicate when casting large items, e.g. what might be the heat output when casting a 1 ton slab that was 20% dicalcium / 50% tricalcium by mass? Students first need to calculate the number of moles etc.<br><br>Discuss an experimental setup, considering the physical state of the reactants and the need to measure any temperature change over time (assume this is over a period of days). Discuss experimental issues, such as heat losses from the system over long periods of time, the SHC of the apparatus as well as the water, etc. |

## Extension / Follow-up ideas

**Speed of reaction**

Gypsum is added to cement to slow down the reactions and prevent 'flash setting'. If salt is added to cement, the opposite occurs as the salt acts as an accelerator. You can demonstrate this using small amounts of Portland cement.

**Complete a risk assessment beforehand using COSHH information on your source of cement and practice first to measure the temperature rise.**

**You will need:**

- Four plastic cups
- 2 stirrers
- Optional: 2 thermometers, but expect to lose these
- 200g cement (NOT concrete mix)
- water
- salt

1. Half fill two cups with cement and two cups with water
2. Add 2 tsp salt to one cup of water
3. 3. Add plain water to one cup of cement – enough to form a paste the same consistency as double cream.
4. Pass this around to show its consistency. Students should feel a little warmth from the slow exothermic reaction. Optional: stir carefully with a thermometer to measure the temperature rise.
5. Repeat but using the salt water. This will set solid almost immediately (so be extremely careful and don't try to mix using the thermometer as it will break – leave this in place).
6. Pass around – it will be very hot but not enough to burn.
7. Discuss the link between the speed of reaction and the temperature rise – the change in enthalpy has now happened in a very short time.

**Is water lost?**

To add to your discussion of what happens to the water added to cement – does it really dry out? – discuss how to test this and see if students can identify the principle of conservation of mass. Ask them to design an experiment to test whether the water evaporates or is trapped in the structure of the set cement. Students can test their ideas experimentally adapting the practical idea above. (You could also include this as an early demo in your lesson.)

Again, ensure you complete a risk assessment before undertaking this activity. Students will need gloves, face masks and eye protection as cement is highly alkaline and as dust is a strong irritant.