*Chemistry > Big idea CCR: Chemical Reactions > Topic CCR3: Energy and reactions*

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| **Key concept (age 11-14)** |
| **CCR3.1: Exothermic and endothermic reactions** |

**What’s the big idea?**

A big idea in chemistry is that during a chemical reaction, atoms are rearranged resulting in the formation of a new substance or substances.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by linking macroscopic observations of temperature change with a sub-microscopic explanation of the energy transfers that arise when atoms are rearranged during a chemical reaction.

****The conceptual progression starts by checking understanding of the dissipation of energy to explain the direction of energy transfer after an exothermic reaction or endothermic reaction. It then supports the development of the idea that energy is always conserved and cannot be ‘created’ or ‘used up’ in order to enable understanding of how the apparent ‘release of energy’ from a fuel is actually the result of the energy required to break apart the reactants being less than that released upon formation of the products.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Exothermic and endothermic reactions**

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| **Learning focus** | During a chemical reaction energy may be transferred to or from the surroundings. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Recognise that energy is conserved during an exothermic reaction. | Describe how the temperature of the chemicals will change with time after an exothermic reaction. | Describe how the temperature of the chemicals will change with time after an endothermic reaction. | Explain the energy changes needed for the rearrangement (breaking apart and combining) of atoms during a chemical reaction.  **B** | Recognise that the overall energy change of a chemical reaction depends on the relative amount of energy needed to separate and combine atoms during the reaction.  **B** |
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| **Diagnostic questions** | Burning fuel | Temperature change 1 | Temperature change 2 | Energy and rearranging atoms | Overall energy change |
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| **Response**  **activities** | Magnesium powder | Exothermic reaction | Endothermic reaction | Molecule models | Energy change diagrams |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Burning fuel** | **Temperature change 1** | **Temperature change 2** | **Energy and rearranging atoms** | **Overall energy change** |
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| Talking heads | Two-tier multiple choice | Two-tier multiple choice | Talking heads | Simple multiple choice |
| **Magnesium powder** | **Exothermic reaction** | **Endothermic reaction** | **Molecule models** | **Energy change diagrams** |
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| Application and practice | Focussed cloze | Focussed cloze | Critiquing a representation | Clarifying |

**What’s the science story?**

The temperature of the chemical system at the end of a chemical reaction may be more or less than the starting temperature. Over time, energy dissipates and is transferred to or from the surroundings and the temperature of the chemical system becomes the same as the surroundings.

The energy required to break apart the reactants may be more or less than the energy released when the products are formed. This is why, overall, energy can be transferred to or from the surroundings.

**What does the research say?**

Kind (2004) summarises three common misconceptions that are described in the research literature:

* Fuels are energy “stores”
* Energy can be created or used up
* Energy is released when bonds break.

In the case of fuels, the use of language such as ‘fuels (or food) contain energy’ gives the impression to some students that energy is some how ‘stored’ in the fuel and is released when the fuel burns. The invisibility of the oxygen that is part of a combustion reaction means that this misunderstanding may be maintained by students unless it is made clear burning is a chemical reaction requiring two reactants.

Other use of language such as “energy running out” when a fuel supply is exhausted can lead students to think of energy as a substance that can be used up. Misunderstandings about burning can also lead students to think that energy can be created.

When students with these misconceptions then learn more chemistry, they can end up extrapolating these misunderstandings resulting in the development of the idea that energy is stored in chemical bonds and is released when bonds break.

Cooper and Klymkowsky (2013) discuss how ‘chemical energy’ is taught across the science disciplines. They suggest that whilst ideas about energy are often introduced in physics first, these ideas are usually at the level of a macroscopic system. In order to understand macroscopic observations of temperature changes in chemical system it is necessary for students to have a sub-microscopic level perspective. Students need to understand the energy transfers to and from the surroundings that are involved in bond making and breaking processes.

**Guidance notes**

Bond breaking actually requires energy to be transferred *from* the surroundings. Energy is transferred *to* the surroundings when bonds are formed. If the products of a reaction have ‘stronger’ bonds than the reactants, then overall energy will be transferred to the surroundings and the reaction will be exothermic.

Please note that at this stage students are unlikely to have been introduced to the concept of a chemical bond. However, the idea of forces of attraction between particles should be familiar to students (see CPS2.1: Atoms and molecules) as well as the idea that atoms are rearranged during a chemical reaction (see CPS3.1 Rearrangement of atoms). Students could therefore think in terms of the energy transfers required to break apart the reactants and to form the products.

**References**

Cooper, M. M. and Klymkowsky, M. W. (2013). The trouble with chemical energy: Why understanding bond energies requires an interdisciplinary systems approach. *CBE-Life Sciences Education,* 12(2)**,** 306-312.

Kind, V. (2004). Beyond appearnaces: Students' misconceptions about basic chemical ideas. [Online]. Available at: <http://www.rsc.org/learn-chemistry/resource/res00002202/beyond-appearances?cmpid=CMP00007478>.