Melting and boiling – the influence of pressure

How does a reduction in pressure lower melting and boiling points?

Does pressure have any effect on the temperature at which changes of state occur between solids, liquids and gases? Try this demonstration with your class (with due regard to safety, since hot water is involved).
Boil some water and pour it into a small dish. From this, fill a 20ml syringe up to about the 15ml mark. (Ensure that air bubbles are excluded by working the plunger up and down a couple of times). Now seal the end of the syringe with a blob of Blutak™ or similar sealant.

Filling the syringe with near-boiling water from a dish.

Hold the syringe up so that all can see it and pull back firmly and steadily on the plunger. As the pressure on the water in the syringe is decreased, bubbles will be seen forming in the water, near the sides of the syringe.

This indicates that the water is boiling, even though the temperature is now well below 100ºC. The bubbles consist of water vapour and not air from outside.

Water in the syringe beginning to boil and to produce bubbles of water vapour as the pressure is reduced by pulling back the plunger.

This can be demonstrated by releasing the plunger, so that it returns to its former position, without any air bubbles appearing. (Note that the plunger needs to be a good fit in the syringe and it is advisable to use a brand-new one where possible).

Demonstrate that the water is well below its normal boiling point of 100º C at atmospheric pressure by squirting it back into the dish and measuring the temperature with a thermometer.

This demonstration of how reducing pressure causes boiling, is linked to how rocks melt at lower temperatures when the overlying pressure is reduced. This is a key cause of melting linked to igneous and plate tectonic activity at divergent plate margins.

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The back up

Title: Melting and boiling – the influence of pressure

Subtitle: How does a reduction in pressure lower melting and boiling points?

Topic: A demonstration of the reduction of boiling point due to reducing the pressure. This provides an analogy with rocks melting at a lower temperature when the overlying pressure is reduced, notably at a divergent plate margin.

Age range of pupils: 16 years and above

Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:

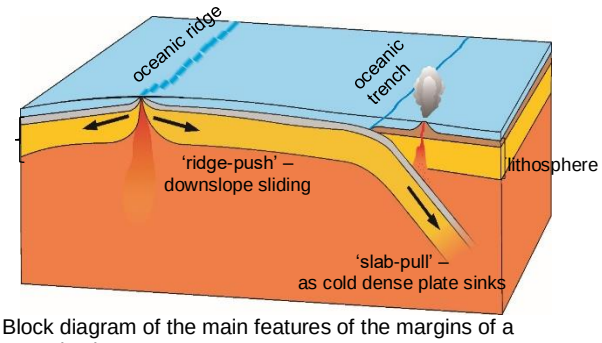
- observe water boiling and turning to water vapour;
- understand the need to demonstrate the lower temperature after the demonstration;
- begin to apply the principle to other changes of state, particularly the generation of magma by pressure reduction at divergent plate margins.

Context: The ambient pressure can affect the change of state when a solid begins to melt or when a liquid begins to boil. Thus at a divergent plate margin, e.g. at an oceanic

spreading centre, the pressure is reduced as hot rock is brought nearer to the surface. This reduces the melting point temperature, causing partial melting of the rock to occur, producing magma, which may then work its way to the surface, to erupt as lava, or crystallise within the crust producing an intrusion. This activity provides a simple analogue of this principle.

Following up the activity:

- Ask pupils to imagine that a mountaineer has time to boil an egg on the summit of Mt. Everest, (8848m) using a camping gas stove. Why would it take a lot longer for the egg to cook than down in the lower lands near Everest, at Kathmandu (1400m)?
- Look at the diagram of a tectonic plate below. How would the melting point of rocks be affected by changes in pressure below the oceanic ridge? (*A. The pressure from overlying rock is reduced as hot rock rises slowly to the surface, thus lowering the melting point, causing the rock to begin to melt*).



Block diagram of the main features of the margins of a tectonic plate

Underlying principles:

- A liquid consists of individual molecules held together by weak intermolecular forces.
- At the surface the forces are not fully balanced and some molecules can escape into a less dense i.e. gaseous medium.
- Reducing the gaseous pressure on the liquid surface allows molecules to escape much more easily; thus less energy is required, meaning in turn that molecules can escape at a lower temperature.
- In most cases solids expand when heated.
- Decreasing the pressure will assist this process by reducing the restraint on expansion, resulting in a lower melting point.

Thinking skill development: For many pupils the idea that a reduction in pressure causes reductions in melting and boiling points is counter-intuitive and sets up a cognitive conflict. Applying the simple analogue to the real world at an oceanic spreading centre requires a substantial bridging skill.

Resource list:

- 20ml syringe
- Blutak™ or similar sealant
- thermometer
- small dish
- kettle
- water

Useful links:

https://www.earthlearningidea.com/PDF/82_Extension.pdf for a more detailed discussion of the relationship between pressure, temperature and the melting points of rocks involved in plate tectonic processes. Also, *What do the top and bottom of a tectonic plate look like?*

Source: Based on an activity described by Pete Loader in *Teaching Earth Sciences* Vol 44.1, 2019, p48.