

The gallium beating heart – technician notes

Education in Chemistry

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Explore redox chemistry with this safer alternative to the mercury beating heart demo

Kit

- Approx 10 ml 1.4 M sulfuric(VI) acid (irritant)
- Approx 1.5 g gallium metal (corrosive)
- 200 cm³ water
- 250 ml beaker
- Sample vial
- Kettle
- Clean iron nails
- Clamp stand and clamp

Preparation

Make a water bath by adding approximately 200 cm³ of 40–50°C water to a 250 cm³ beaker. Suspend the sample vial in the water and add 1 M sulfuric acid to a depth of 1–2 cm.

The hot water bath can be used to melt your sample of gallium (melting point: 29.76°C), which will have been supplied in a plastic container. Add a droplet approximately 5–7 mm in diameter (approx 1.5 g) of the liquid metal to the acid. Most sample vials have a slight camber to the base which will cause the droplet to sit towards the edge of the vial – if not, you may need to tilt the vial slightly to encourage this. A second clamp can be used to hold the tip of a clean iron nail next to the droplet.

When the nail is in electrical contact with the droplet, the droplet will contract and pull away from the nail. When the two are not in electrical contact, the droplet will sag and spread towards the nail. By carefully adjusting the position of the nail, a position can be found such that electrical contact is re-established only when the droplet sags and is broken when it pulls away – leading to a cyclical ‘beating’ motion.

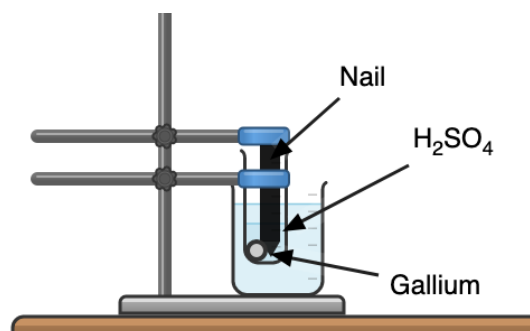


Figure 1: Experimental setup

In front of the class

Once established, the ‘beating’ oscillation will continue for at least 30 minutes. Students can come up to inspect individually or in small groups, or a USB camera can be used to share details with the whole class.

Literature descriptions of this demonstration call for the use of significantly more concentrated acid, higher temperatures and often the superfluous addition of dichromate salts which produce a beating effect without the iron. The motion of the droplet is sensitive to its contact angle with the surface, its electrical contact with the iron, the temperature and the concentration of the acid. Should this reaction not work for you with a clean iron nail, then a larger gallium droplet, higher temperature, or greater acid concentration will stimulate it. Note that above 1.5 M sulfuric acid is classified as corrosive.

Disposal

Gallium can be rinsed thoroughly in the vial and allowed to air dry before replacing the cap for future demonstrations. Though gallium should not be stored in glass due to the fact it expands on freezing, the small size of the droplet compared with the diameter of a sample vial does not present a hazard.

Minimise the number of containers that the gallium comes into contact with as it will efficiently wet many surfaces – including glass, plastic and skin – and leave a residue that can amalgamate with (ie, form an alloy) and weaken other metals like aluminium and gold. This very thin film is then very difficult to remove.

Health and safety

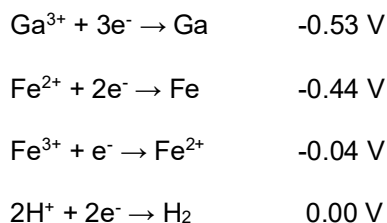
- CLEAPSS members should refer to [HC001B](#) and [SRA037](#).
- Wear eye protection.
- Avoid skin contact with gallium metal. Wash hands with soap and water following skin contact. Use nitrile (type B) gloves if contact is likely.

Teaching goal

This demonstration shows an intriguing application of a chemical to kinetic energy transfer. Delving deeper gets a little more complicated!

Previous descriptions of this demonstration and the mercury beating heart explain the phenomenon in terms of a spontaneous redox process where the metal droplet is oxidised by the solution in which it's submerged. The oxidation products produce a surface film, lowering the surface tension of the droplet and bringing it into contact with the iron. Electrons are transferred between the metals which reduce the surface film and cause the droplet to contract away once more.

The logic follows for mercury, which has a lower activity than iron – but gallium has a higher activity, suggesting that the iron alone will not be reducing gallium(III) at the droplet surface when we look only at the predicted redox potentials.



Based on this logic, other instructions for the gallium demonstration involve the addition of chromate(VI) ions, which are said to initiate the oxidation of the droplet. However, gallium will clearly be oxidised in acid without assistance, and, even for the mercury reaction, exposure to oxygen in the air is enough to initiate oscillations.

A more subtle effect is clearly at work.

As explored in a previous Exhibition Chemistry, '[Nailing corrosion demonstrations](#)', the introduction of a metal to a solution will set up an equilibrium between oxidised and reduced forms of the metal at the interface. As metal ions dissolve into the solution immediately surrounding the metal, solvated metal ions gather and are attracted to the negative charge left on the metal surface. An electrical double layer is established. The shape of liquid metals can respond to this change in charge distribution: repulsive forces at the surface, and attractive forces to nearby solvated ions serve to reduce the surface tension and the droplet sags.

As the gallium and iron are added to the acid, both react to produce hydrogen gas. If the gallium droplet is close enough to the nail, electrical contact can be made where negative charge will flow to the nail, accelerating the production of hydrogen gas here. With the loss of negative charge, the double layer around the droplet is disrupted, the surface tension increases and the droplet pulls away from the nail again. The process can now repeat and will likely be aided by the hydrodynamics and inertia of the droplet forming a natural 'jiggle'.