An Exothermic Phase Transition for 25¢

Introduction:

This is a very effective visual model of an exothermic phase transition.

Chemical Concepts:
Exothermic event
Metal alloys
Phase transition
Metals used in coinage

Materials:
US Quarter (dated prior to 2000)
Methanol
Propane Torch
150 mL beaker
A wet piece of wood to cover the beaker

Procedure:

Use a hot Bunsen burner or propane torch to heat a US quarter very hot (it needs to be as red hot as you can get it). Since you are holding it with tongs, move it rapidly to a 150-mL beaker with 100 mL of methanol in it. Drop the red hot quarter into the methanol.

If the vapors ignite as the coin drops in, cover the beaker with a small block of wet wood, or other device to snuff out the flame.

The quarter will boil the methanol.

After the liquid has stopped bubbling, watch carefully.

A phase transition appears to take place-releasing heat, which causes a rush of bubbles as more methanol boils. The quarter will now appear pink as a fine layer of copper has migrated through the nickel coating! This layer can be polished, or scraped off revealing the nickel cladding underneath.

SAFETY PRECAUTIONS:

[These suggestions are NOT intended to be a complete review of all the safety issues involved with this activity. Professional judgement and practices are essential. If you are unsure of the safety precautions that should be taken, seek experienced assistance.]

1. Add the methanol to the beaker and then seal the supply bottle before lighting the torch. Methanol vapors can flash back into the bottle causing an explosion. Keep the torch at least one metre away from the alcohol.

2. When the coin is dropped in to the alcohol, it may catch fire. If the alcohol splashes, the fire may spread to the bench. Although it is a cool flame, be prepared for this event by wetting the bench surface with water ahead of time.

3. Once the demonstration is over, be sure that there is no flame burning in the beaker before removing the coin.

4. If possible, use a video camera to show the release of bubbles to the class. Students should NOT be allowed to cluster around the bench to see the event.

DISPOSAL:

The cooled methanol can be re-used for solvent purposes.

The coin should NOT be returned to circulation (see discussion).

DISCUSSION:

The US mint states that the structure of the US quarter (prior to year 2000) is a core wafer of pure copper, clad in a 75% Cu / 25% Ni alloy.

Obviously, this alloy is unstable and another alloy richer in Ni is more stable. Copper released from this mixture floats to the surface and can be removed in flakes by careful use of a scalpel.

Most textbooks show that there is ONE stable phase of Cu:Ni alloy , a face-centred cubic structure that forms as the mixture cools down to 1000^{o}C.

The intense heating allows the copper to mix with (or float up through) the nickel cladding. The sudden release of bubbles is likely an example of the "Leidenfrost" effect. The alcohol forms a vapour layer around the coin slowing the rate at which heat can escape. When the liquid stops boiling, the insulating vapour layer around the coin collapses and the coin-liquid contact is more efficient at transferring heat away from the metal. This results in a sudden rush of bubbles as the coin cools to below the boiling point of methanol. The collapse of the gas layer also reveals the new colour of the coin. This mimics an exothermic phase transition and is a dramatic way to illustrate how a physical (or chemical) change can result in a sudden release of energy.

[Note: the late Cliff Schraeder received a letter in July 2000 from the US mint confirming that making a few "brass pennies" and, by extension, this demonstration, is not objectionable if it is done for educational purposes and is not done to misrepresent the value of the coins. The removal of the copper from the alloy will change appearance and perhaps the electromagnetic properties of the coin (used in vending machines) and thus it should not be returned to circulation.]