Name ________________________________ Date __________________________

Activity 1: Gel-Heating Pad

Introduction:
The gel-heating pad used in this investigation is shown in Fig. 1a. It is manufactured for use in keeping hands warm inside gloves or for medical heat treatment purposes. Once activated, the pad will maintain therapeutic temperatures for 15-20 minutes and will be warmer than the surroundings for up to 30 minutes. Heat storing devices using supercooled salt hydrates such as sodium acetate date back over 100 years. The present form of the heat pad with the metallic trigger appeared in the late 1970s. How do these gel pads work?

Fig 1a,1b, and 1c Hot gel and warm mate pads, flexible disk trigger, and spring-type trigger.

The “hot gel” and “warm mate” heat pads are shown in **Fig 1a**. The flexible disc is shown in **Fig.** 1b and the spring-type trigger in **Fig. 1c.** The flexible disk trigger is 19 mm in diameter and is the type in your gel pad. Before discussing the gel pad, here is a simple analogy with supercooled water and the formation of ice. What is happening with the gel pad appears strange, but the process can be understood if you think about water freezing. Water freezes at 32 degrees Fahrenheit (0 degrees C). If you were to stick a thermometer in a cup of water and put the cup in the freezer, you would find that the temperature of the water falls to 32 degrees F and then hangs there until all the water is completely frozen. Then the temperature of the solid water falls to the temperature of the freezer. What happens if you **supercool** the water? Suppose you could get the water's temperature to 10 degrees below the freezing point without it crystallizing into a solid (ice). You can do this if you fill a very clean glass with distilled water and place it in your freezer. Because the water is distilled, there are no points for the water to begin crystallizing. However, if you tap the glass the temperature of the water will jump up to 32 degrees F (0 degrees C), and the water will solidify quickly. The pad works in a similar manner.

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Your gel pad contains **sodium acetate** and water. Sodium acetate is very good at supercooling. It "freezes" at 130 degrees F (54 degrees C), but it is happy to exist as a liquid at a much lower temperature and is extremely stable. Clicking the disk by squeezing the pad with your hands. This forces a few molecules to flip to the solid state, and the rest of the liquid then rushes to solidify as well. The temperature of the solidifying liquid jumps up to 130 degrees F in the process. When the liquid crystallizes, the energy associated with the phase transition, the latent heat of fusion, is released and the temperature increases to the melting/freezing point temperature of the substance, which for sodium acetate trihydrate is 130 degrees F °C. which is high enough to keep your hands warm. Once activated, heat pads can be re-used but will look very different than when they are new. Pads can be reused by submerging the pad in a hot water bath with a cloth on the bottom as a caution against sticking. Once cooled to room temperature the pad is ready to be used again. It won't look the same as it did when new.

More details on crystallization

The super-cooled liquid is metastable because of a nucleation barrier that prevents the growth of macroscopic particles of crystalline material. A spontaneous transition to the solid phase will not occur. The heating pad contains a trigger device that can be manipulated by the user to initiate the crystallization of the super-cooled liquid. The flexing of the 19 mm disk shown in **Fig. 1**b causes "a single molecule to crystallize and subsequently nucleation occurs throughout the super-cooled liquid. One proposed mechanism is friction between metal layers of the disk as it is snapped. This friction produces molecular vibrations throughout the liquid causing nucleation to occur throughout the crystal. The crystals grow quickly, approximately 5 mm/s, and the solid phase has a polycrystalline structure shown in **Fig. 2.**

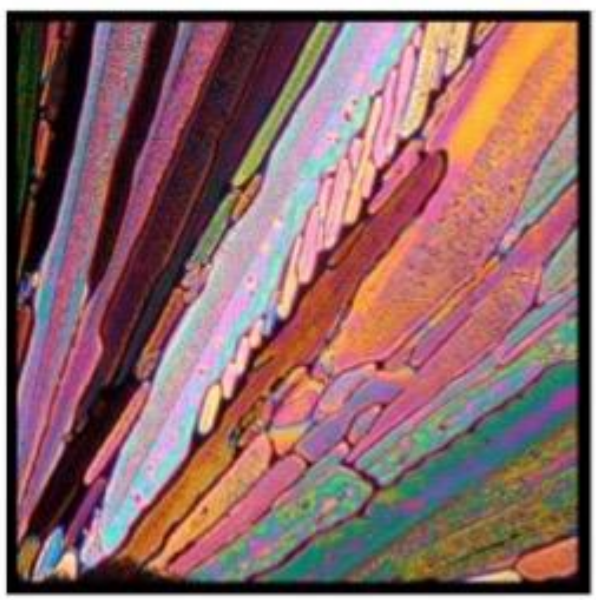

Fig. 2 The art of sodium acetate trihydrate crystals. A drop of the solution was placed between two microscope slides, and crystallization of the supercooled liquid was seeded from one edge. The images show the polycrystalline structure observed between crossed polarizers in a microscope using a 5X objective.

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Objective: To understand the energy transformations occurring in a gel heating pad and to measure the temperature of the gel as a function of time.

Virginia SOLs: PS.1b, PS.1d, PS.1k, PS.1m, PS.2f, PS.5c, PS.6b, PS.6c, PS.7a, 3.1h, 3.1j, 6.1c, 6.1h, 6.2e

Suitable for students in grades 6-12

Materials:

- Gel Heating Pad
- Thermometer
- Pan of boiling water
- Cloth

Procedure

1. Describe the contents of the pad. Are there liquids? Are there solids? What shapes do you see? What color are the contents?

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2. Hold your thermometer firmly against the center of the pad. Be sure to only hold the top part of the thermometer. Record the starting temperature of the pad.

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3. To start the heating pad, flex the metal disc up and down on the curved center until you hear a "click - click" sound.

4. In order to fully activate the pad you should mold and shape the gel to evenly distribute the contents.

In **Table 1**, record the temperature of the pad every minute for 20 minutes. In between readings, record your observations about changes in the physical characteristics of the pad (color, texture, clarity, etc.).

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Table 1

Time (minutes)	Temperature Degrees °C	Observations
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
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14		
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17		
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19		

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20		

5. In words, describe how the temperature changes with time through the 20 minutes.

6. Where do you think the energy came from that resulted in the temperature of the pad increasing? Support your answer with your data and/or observations.

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7. Place the pad in a pot of water bath with a cloth on the bottom as a caution against sticking. Bring the water should be brought to a boil until the crystals have melted to a clear gel. Hold the pad against the light to check and shake the pad to dissolve the remaining crystals. Cool to room temperature so that the pad is ready to be used again. What energy transformations have take place to put the pad back into a reusable condition?

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References

1. B. Sandness Am. J. Phys., Vol. 76, No. 6, June 2008

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