RUBBER BANDS AND FREE ENERGY

Introduction

Not all changes in the free energy of a system are a result of chemical changes. When solids melt the entropy and enthalpy of the substance changes. This means that the free energy of the substance in its new state has also changed. A similar change in free energy takes place when rubber is stretched. Rubber bands are flexible because rubber is a polymer – a long chain of molecules of repeating units (isoprene units in the case of rubber). In this lab, you will take a look at how stretching a rubber band affects the enthalpy, entropy, and free energy of the rubber.

SAFETY; Be careful when handling the rubber bands and lights.

Procedure

Answer each question (in bold) in the procedure as you come to them, NOT at the end of the lab. You will need the information to continue with the lab.

Part I

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1. **What is the spontaneous condition for a rubber band – stretched or unstretched?**
2. **What does this tell you about the change in free energy when a rubber band is stretched? Explain.**

a) Touch an unstretched rubber band against your forehead for a few seconds and then remove it. Make a mental note of the temperature.
b) Now hold it close to your forehead, stretch it until it is about three times its original length, and *quickly* touch it to you forehead. Note any temperature change. Repeat the steps several time, if necessary, until you are certain of the results.
c) Stretch the rubber band so that it is about three times its original length and hold it in the air for about 20 seconds. Now let it contract carefully and *quickly* touch it to your forehead. Note any temperature change.

3. **Is the change from unstretched to stretched endothermic or exothermic? Explain.**
4. **Determine the sign (positive or negative) for ΔG and for ΔH. What does this tell you about the change in *entropy* for stretching a rubber band?**
5. **Write the equation for the change in free energy. Show whether the sign for each term will be positive or negative. How does the magnitude of the entropy change (TΔS) compare with the magnitude of the change in enthalpy ΔH (which one represents a larger change in energy)?**
6. **Draw an energy diagram that shows the relative changes in enthalpy, entropy, and free energy for stretching a rubber band.**

Part II

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7. **In the next step you will heat a stretched rubber band. Based upon what you learned in Part I, what do you predict will happen to the rubber band?**

a) Cut a strip 10 cm long from a rubber band. Tie one end to a finger clamp and the other end to a 150-gram weight. Attach the clamp to a ring stand. Adjust the height of the clamp so that the weight rests on an electronic balance with a registered mass of approximately 20 g. When the balance reading stabilizes, record it.
b) Bring a high-intensity light bulb as close as possible to the rubber strip without touching it and turn it on. Record any changes for about 45 seconds.

8. Does the response of the rubber to heat agree with your prediction? Explain.
9. Based on your observations, explain how the orderliness of the isoprene polymer molecules in rubber changes between the stretched and unstretched conditions.

Part III

In Part II of the rubber band investigation, you found that increasing the temperature of the rubber band caused it to contract further into the unstretched condition. This is a reasonable result if you consider how increasing the temperature "T" will affect the $T\Delta S$ term in the free energy equation. But we can also look at this result from a different point of view – from the standpoint of equilibrium. Let's start by looking at another reaction. $2NO\ (g) \longleftrightarrow N_2\ (g) + O_2\ (g) + 180.5\ kJ$

10. The equation above represents a reversible reaction that favors the products. Explain what this means.
11. Describe what has happened when this reaction reaches equilibrium.
12. Is this reaction endothermic or exothermic and how can you tell?
13. What specifically would happen if heat energy were added to this reaction at equilibrium?
14. Use Le Chatelier's principle to explain this result.

Now, back to the rubber band. We can think of stretching a rubber band as a reversible reaction at equilibrium.

15. Write an equation using the stretched and unstretched conditions for a rubber band. Substitute the unstretched condition for the reactants and the stretched condition for the products. Heat energy is exchanged with the surroundings when a rubber band is stretched. Is it a reactant or product? Include this heat energy term in the rubber band equation.
16. How would hanging a 100-g mass from the rubber band affect the equilibrium of the rubber band equation? Include its affect on the heat energy term.
17. Using Le Chatelier's principle, explain how heating a rubber band would be expected to effect the equilibrium position of the equation. Does this agree with your previous observations from the first part of the lab?
18. Design an experiment that would test the effect of removing heat energy from a slightly stretched rubber band. You will not perform this experiment, but the materials you intend to use should be ones you would normally find here at school. Include in your design:
- **A list of the materials required.**
- **A brief description of the procedure you would use.**
- **The observations you would expect to see. Explain these observations in terms of both free energy changes and equilibrium.**