Physics Invention Sequences Users' Guide: Specific and Latent Heats

SPECIFIC AND LATENT HEATS INVENTION SEQUENCE

Includes: *resistance to temperature change index RTC (heat capacity), mass RTC index (mass specific heat), phase change heat index (latent heat)*

Teacher Notes: College physics students have all taken high school chemistry, and very few understand what the specific and latent heats are. They get mired in the algebra and units and have a very weak sense of what these properties tell us about materials. One problem is the use of unnecessarily technical (and unenlightening) terms, another is that a large heat capacity results in a small temperature change, a notion that is confounded by the fact that students confuse heat and temperature.

Levels: This sequence is appropriate for courses that teach specific and latent heats.

Resistance to Temperature Change Index [RTC Index]

You are a chemical engineer working for Toyota, and your job is to research the best coolants to use for their engines. The three identical beakers below are filled with the same mass of three different coolants. They are set in the same position on the same heater and heated for different amounts of time. Assuming the heater heats at a steady rate, the energy transferred to the coolants (shown below) then is proportional to the time that the pan is heated. You want to characterize the **coolant samples** based on their *resistance to temperature change*. The index should be largest for the object that is the most resistant to temperature change, after all a better coolant's temperature doesn't increase easily.

Cool Running
3000 J of heating resulted in a temperature change of 2 K

ChillerAde
7500 J of heating resulted in a temperature change of 3 K

Engine Relief
8000 J of heating resulted in a temperature change of 4 K

	Cool Running	ChillerAde	Engine Relief
Resistance to temperature change index			

1. What does the RTC index tell you about the coolant?

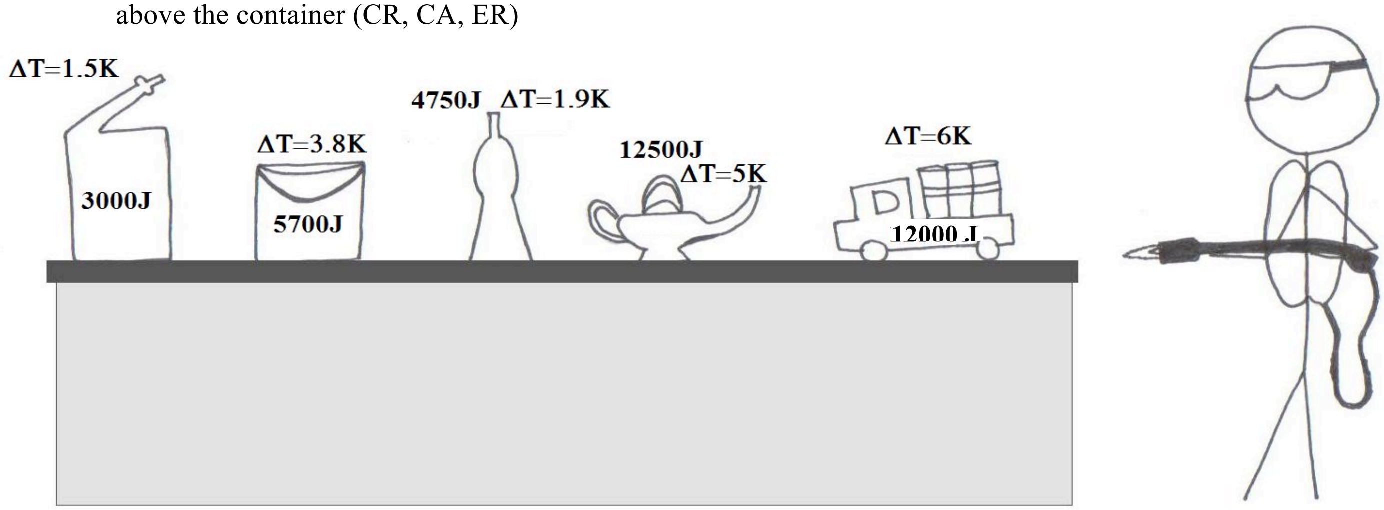
2. Write an equation for the following statement:
   It takes 100 joules of heating to change the temperature of a liquid by 1 degree Celsius.

   Use Q for the amount of heating and ΔT for the temperature change.

3. What does the number 100 tell you about the coolant in 2?

II Name that coolant!

There is going to be an inspection of your lab by the hazardous materials safety board. They insist that all liquids be labeled, but you've been a bit negligent and you now have 5 containers of unlabelled coolants. Each container holds the same amount of coolant. You decide to heat them, and measure their temperature changes to figure out which coolants they are.
The information is shown below; please sort the coolants. You can write the coolant's initials above the container (CR, CA, ER)



Mass RTC Index

As long as you always measure out the same amount of coolant, you can predict how much the temperature will change knowing its RTC index. What if you want to use different amounts of coolants? You know that if you use twice as much coolant you will have to heat it longer to get the same temperature change.

You decide to create an index that is not dependent on having the same amounts of coolants when you want to compare them, you'd like the index to characterize the coolant regardless of the amount.

So you decide to conduct an experiment. You take one coolant and pour out 4 samples - two that have a mass of 0.5 kg and two that have a mass of 1.5 kg. You heat each sample by a different amount and measure the resulting temperature change. Now your job is to create an index that is the same for all 4 samples. It is an index that characterizes the RTC index of the coolant itself, not just the particular sample of the coolant.

Experiment	Energy transferred, Q	Temperature change, ΔT	mass, m	INDEX
1	25,000 J	10 K	0.5 kg	
2	10,000 J	4 K	0.5 kg	
3	15,000 J	2 K	1.5 kg	
4	30,000 J	4 K	1.5 kg	

Follow up questions

1. Let the mass RTC index be represented by the symbol "c". Write an algebraic equation that relates the amount of heating, Q, to the Temperature change, ΔT, the mass, m and the mass RTC index, c.
2. Write an equation for the following statement:

It takes 100 joules of heating for every kg of a liquid to change its the temperature by 1 degree Celsius.

Use Q for the amount of heating, m for the mass of the liquid and ΔT for the temperature change.

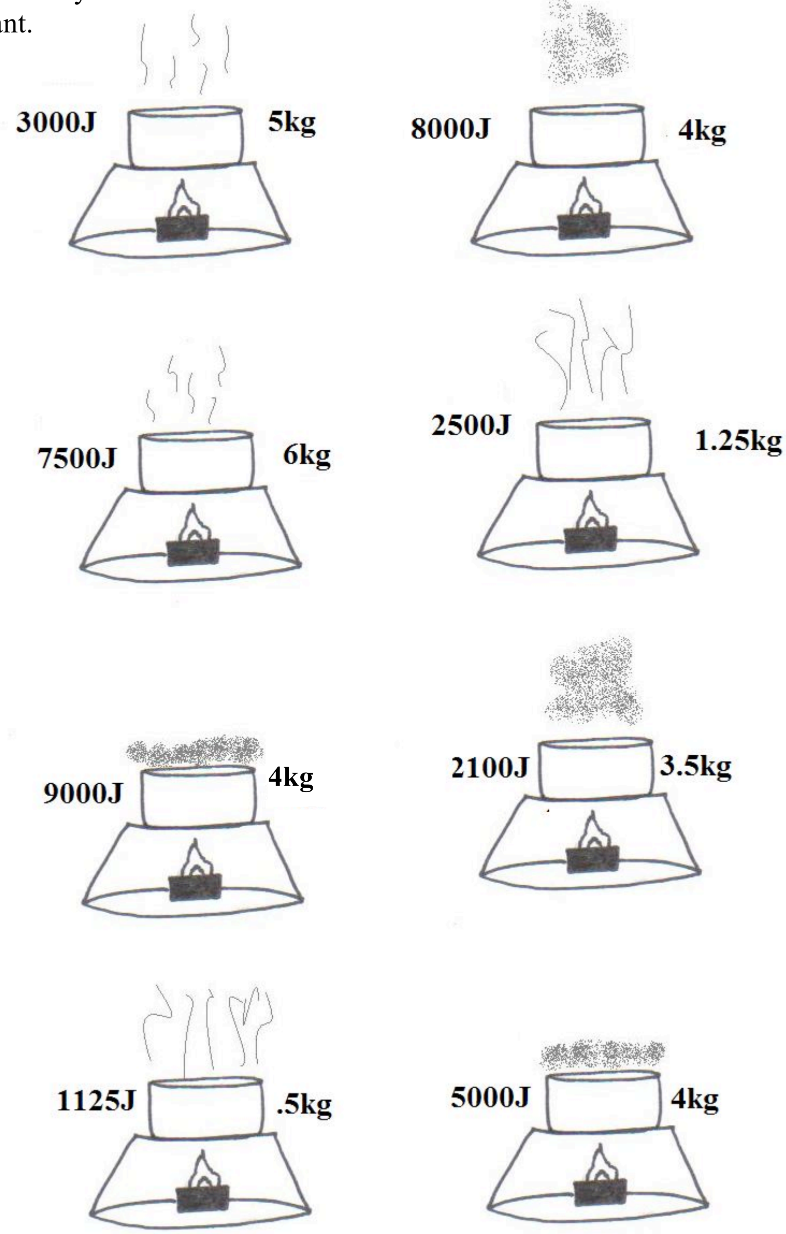
3. If the amount of coolant in part I is 0.5 kg, which coolant was used for the experiment described above?
4. How much energy is necessary to raise the temperature of 2 kg of the coolant above by 3K?
5. How much will the temperature change if 1.3 kg of this coolant experiences 42,000 J of heating?
6. The mass RTC index of water is 4180 J/kg·K . How much heating is necessary to increase the temperature of 500 g of water by 5 K?

Phase Change Heat Index

You continue experimenting with the coolants and want to map out the response to heating at very high temperatures. You see that the temperature steadily increases with heating until the coolant starts to boil, during which the temperature stays steady as the coolant vaporizes to a gas.

You are well aware that you must continue to heat the liquid if you want it to transform from a liquid to a gas.

You want to characterize the coolants by inventing a **phase change heat index** based on how much heating is necessary to transform samples from liquid to a gas. Your data, which includes the amount of energy transferred and the mass of the liquid that vaporizes, is shown below for 4 different samples of coolant. Can you find which ones are the same coolant? Draw lines connecting the pictures of the same coolant.



Follow up questions

1. How does the temperature change of a liquid (that doesn't boil) depend on the amount of heating or cooling (linear, parabolic, etc.)?

2. What happens to the temperature when a liquid is vaporizing?

3. Let the latent heat be represented by the symbol "L". Write an algebraic expression that relates the amount of heating, Q, to the Temperature change, ΔT, the mass, m and the latent heat, L.

4. The specific heat capacity of water is 4180 J/kg·K . How much heating is necessary to increase the temperature of 500 g of water by 5 K?

5. The latent heat of vaporization of water is 2.257×10^6 J/kg. How much heating is necessary to transform 500 grams of liquid water into 500 g of steam at 100ºC?

Summary Questions

1. If the amount of coolant in part I is 0.5 kg, which coolant was used for the experiment described in part III?

2. How much energy is necessary to raise the temperature of 2 kg of the coolant in part III by 3K?

3. How much will the temperature change if 1.3 kg of the coolant in part III experiences 42,000 J of heating?

4. Write an equation for the following statement:

It takes 100 joules of heating to change the temperature of a liquid by 3 degrees Celsius.

Use Q for the amount of heating and ΔT for the temperature change.

5. If you want to characterize a metal's response to heating, which index makes the most sense – the RTC index or the mass RTC index? Explain your choice.