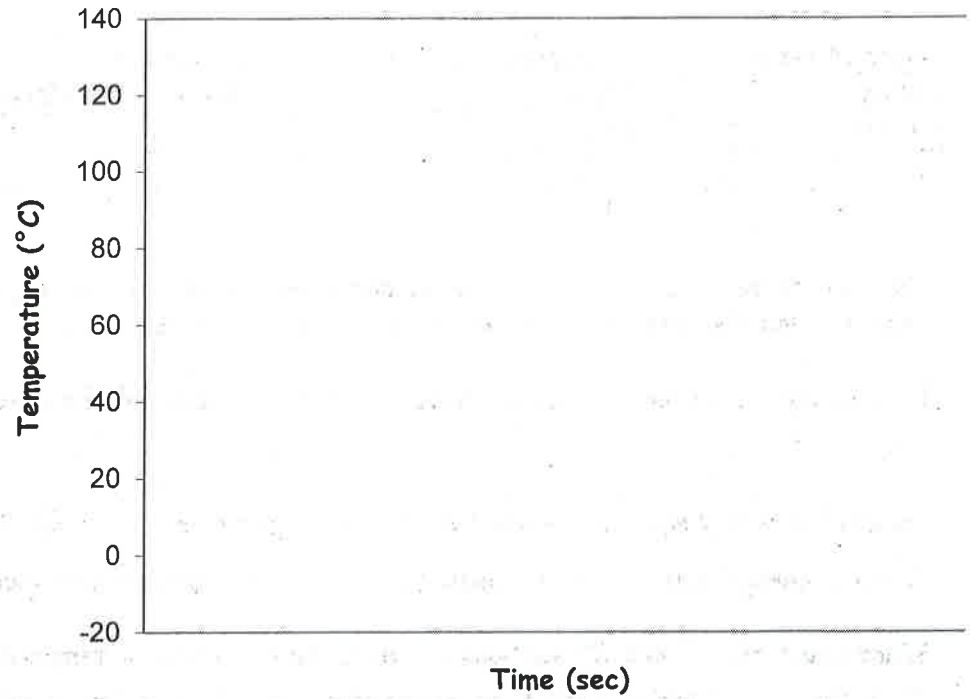
Cooling Curve for Water at 1 atm



...w of Conservation of Matter

- matter can also be transformed during chemical and physical changes
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- example: when ice melts to make water during a phase change, every molecule of H_2O in the original ice crystal/cube can be accounted for in the resulting liquid H_2O
- example: when two chemicals are mixed, the atoms may be rearranged to form new chemical compounds, but every original atom can be accounted for in the new substances

(on our large scale, we see matter and energy as separate, but matter and energy interconvert at the subatomic level according to Einstein's Theory of Relativity $E = mc^2$)

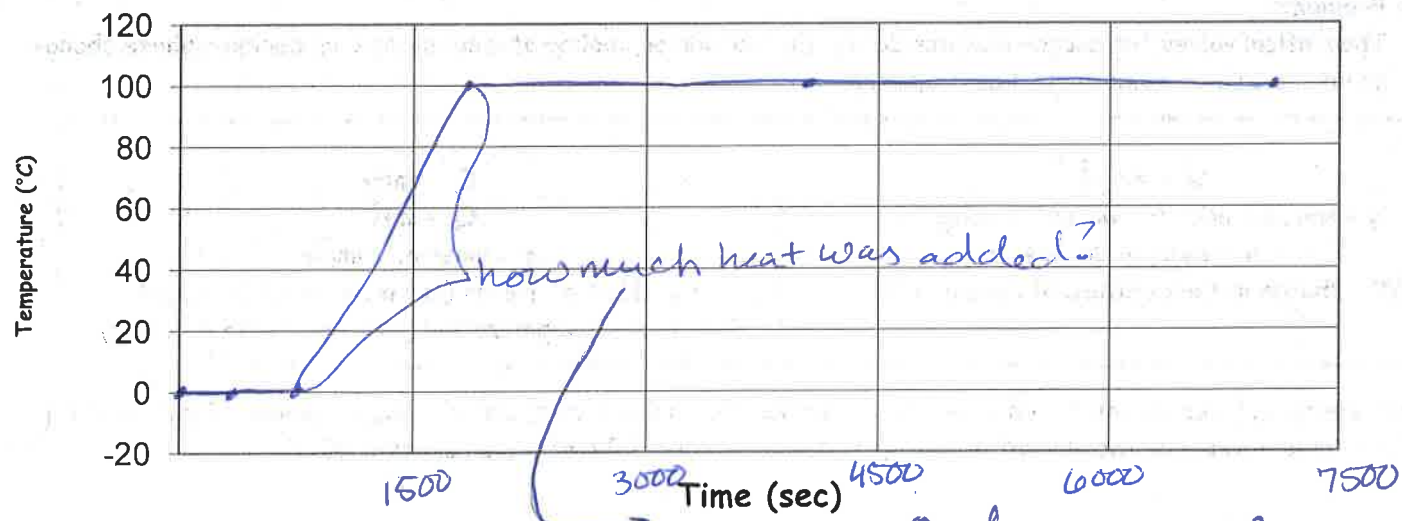
* A quantitative look at the heating curve for water

Water Temperature and Time Measurements* (100. g of ice made from distilled water, heat added = 10. cal/sec)

Time (sec)	Temp (°C)	Observations
0.	0.0	ice beginning to melt
400.	0.0	mixture of melting ice and water
800.	0.0	last of ice melted; only water present
1800.	100.0	water beginning to boil
4000.	100.0	boiling water (less than the original amount) and steam/vapor
7200.	100.0	last of water turned to vapor

Plot this data on the following graph, please connect the dots (do not draw a best fit line).

Heating Curve for Water at 1 atm



$1000 \text{ sec} \times \frac{10 \text{ cal}}{\text{sec}} = 10000 \text{ cal}$

Heating Curve Logic: if heat is added at 10 cal/sec for 1000 sec...how many calories are added?

Mass of water	Temperature change	Calories added
100 g	100 °C ÷10	1000 sec x 10 cal/sec = 10000 cal
100 g	10 °C ÷10	1000 cal
100 g ÷100	1 °C	100 cal
1 g	1 °C	1 cal

That means we need 1 cal **of heat to raise the temperature of** 1 g **of water by** 1 °C!
That is called the specific heat capacity = c = 1 cal/g°C for water.
↳ energy required to raise 1 g of liquid water by 1°C

Knowing that, how many calories do we need to raise the temperature of 10 g of water from 50°C to 75°C?

25°C x 10g = 250 cal 250 cal 75°C - 50°C = 25°C

Here is the formal equation for what you just did logically → $Q = mc\Delta T$

Q = heat energy (cal) m = mass (g) c = specific heat (cal/g°C) ΔT = temperature change (°C)

What about the 1st and 3rd sections of the graph? There is no temperature change...so this equation won't work...

1st section: Lasted 800 sec, if we were adding heat at 10 cal/sec → we added 8000 calories
Those 8000 calories were able to melt 100 g of solid water.
So...we need 80 calories to melt 1 g of solid water.
melt s → l
↳ energy required to melt (s→l) 1g of substance

That is called the heat of fusion = H_f = 80.0 cal/g for water

$$Q = mH_f$$

Q = heat (cal) m = mass (g) H_f = heat of fusion (cal/g)

3rd section: Lasted 5400 sec! If we added heat at 10 cal/sec → we added 54000 calories
Those 54000 calories were able to vaporize (boil) 100 g of liquid water.
So...we need 540 calories to vaporize 1 g of liquid water (turn it all into gas).
boil
↳ energy required to vaporize 1g of substance

That is called the heat of vaporization = H_v = 540 cal/g for water

$$Q = mH_v$$

Q = heat (cal) m = mass (g) H_v = heat of vaporization (cal/g)

Calorie Problems

- Theoretical values for energy changes during the heating or cooling of a substance, or during a phase change, can be calculated using three basic equations.

$Q = mc\Delta T$ c = specific heat for water = 1 cal/g °C m = mass of sample ΔT = change in temperature of sample in °C	$Q = mH_f$ $Q = mH_v$ m = mass of sample H_f = heat of fusion (for water = 79.72 cal/g) H_v = heat of vaporization (for water = 539.4 cal/g)

The heat energy (Q) can be calculated in terms of calories (cal), kilocalories (Cal or kcal), or joules. (1 calorie = 4.18 cal) A calorie is defined as the amount of energy required to raise 1.0 g of water exactly 1.0 °C.