

# Chemistry Internal Assessment

## RELATIONSHIP BETWEEN SALINITY OF WATER AND SPECIFIC HEAT CAPACITY

word count:—

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# 1 Introduction

Specific heat capacity is a measure of the amount of energy required to change the temperature of a 1 kg object by 1 K. It is an important concept as it gives an indication of how much energy and time is required to heat or cool an object and consequently the cost – something of significant importance for many industries. For simplicity we often assume that water and aqueous solutions have the same specific heat capacity. The fundamental reason as to why there is such a change is beyond the scope of this paper, however, attempting to quantify it presents an interesting question. In order to minimise any safety concern and the ease of reproducibility, I opted specifically for investigating the relationship between salinity and specific heat capacity – from deionised water to about 3.5% salinity, approximately what is found in seawater.

As we seek to explore the relationship between the salinity and the solutions specific heat capacity, this exploration will consist of using a kettle to heat up water of varying salinities, using software to track the change in temperature, and ultimately calculate their specific heat capacity. Formally, the research question is: **How does the salinity of a solution affect its specific heat capacity?**

**Hypothesis (to be better phrased)** If we add 10% of compound A with  $c=1$  and 90% of water with  $c=4$ , should we expect  $c = 0.1 \cdot 1 + 0.9 \cdot 4 = 3.7$ ? or does the disassociation have an effect?

## 2 Background knowledge

We may express a relationship between heat, a form of energy, and the following characteristics of a material: mass ( $m$ ), specific heat capacity ( $c$ ) and the change in the temperature it undergoes ( $\Delta T$ ), as follows:

$$\Delta H = mc\Delta T$$

Central to our calculation is the concept of power, which we may tie with the heat equation:

$$\begin{aligned} Power &= \frac{Energy}{time} \\ \therefore P &= \frac{mc\Delta T}{\Delta t} \end{aligned} \tag{1}$$

Finally, when dealing with a change in phase (such as from liquid to gas), it is also important to discuss the amount of energy required to undergo that change at a constant temperature; hence, a plateau will be seen at the end of the time x temperature graphs that later will be presented. As this does not concern heat capacity, it will be trimmed from the graphs.

## 3 Procedure

Write in more details:

1. Known mass of water and salt added to kettle. Put Logger pro or other software thermometer inside kettle tracking every 5 seconds.
2. Run until water boils

### 3.1 Procedural concerns

- Have to use same kettle for all trials. It has a collection of limescale and other salts in it. Systematic error?
- The uncertainty on the kettle is about 5%. Much larger than the 0.01% we have on the masses.
- Argue for data collection of every 5 seconds vs every second vs 0.1 seconds to establish more manageable data sets.
- Visually having to pick where the experiment “begins” from each trial. Compare to result including the time the kettle takes to get started??

### 3.2 Variables

**Independent** Salinity of solution ( $\text{g l}^{-1}$ )

**Dependent** Change in temperature over change in time. ( $^{\circ}\text{C s}^{-1}$ ) **What would be the uncertainty in time given that we’re working with a change in time, as precisely defined by the computer? I suspect zero.**

**Control Variables** Power output of kettle:  $(2000 \pm 200) \text{ W}$ . Mass of water:  $(766 \pm 70) \text{ g}$ .

### 3.3 Considerations

The masses of water need not be exactly the same, as we will produce “normalised” graphs. That is, by multiplying each temperature data point by the mass, we use the graph to better compare the data. This also means that the mass of salt must be changed accordingly as to produce the salinity of each sample.

By comparing the found specific heat capacity for 0% salinity, we can establish the systematic error, which consists of the efficiency of the kettle and the collection of salts still present in the water and in accumulated on the kettle. It is suspected that the former is of greater importance than the latter, so both will be mostly accounted for with our calculation for efficiency.

The power output range of kettles varies greatly, therefore it is crucial to find one with the smallest range possible. The overwhelming majority of the instrumental uncertainty comes from the kettle (10% compared to less than 0.1% for the mass) uncertainty of the kettle: 1) Establish efficiency by comparing table value with found result for 0% salinity. 2) Instrumental uncertainty is really high, so results may be unreliable

## 4 Data

## 5 Analysis

The extremities of the raw data include a period before the kettle is fully operating and after it has turned off, as well as other oddities, so it is trimmed. Furthermore we normalise our graphs by 1) multiplying the temperature at each data point by the sample's mass, and 2) shifting the graphs to have the same initial temperature. This not only corrects for the variation in mass of each sample, but it allows us to use the slope of the curves to calculate the specific heat capacity.

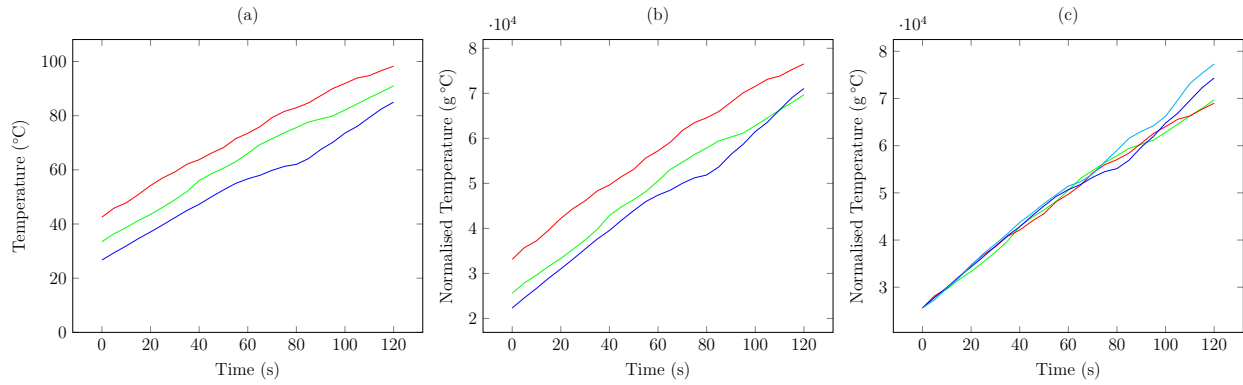


Figure 1: 0% Salinity data being normalised. (a) we have the removal of end points; (b), multiplication by the mass of sample. (c), shift the graph to have a same initial normalised temperature.

From equation (1) we had

$$P = \frac{m\Delta T}{\Delta t}c$$

$$\underbrace{m\Delta T}_y = \frac{P}{c} \cdot \underbrace{\Delta t}_x$$

Fully processed data: Thus we calculate the efficiency (e) by comparing the 0% salinity

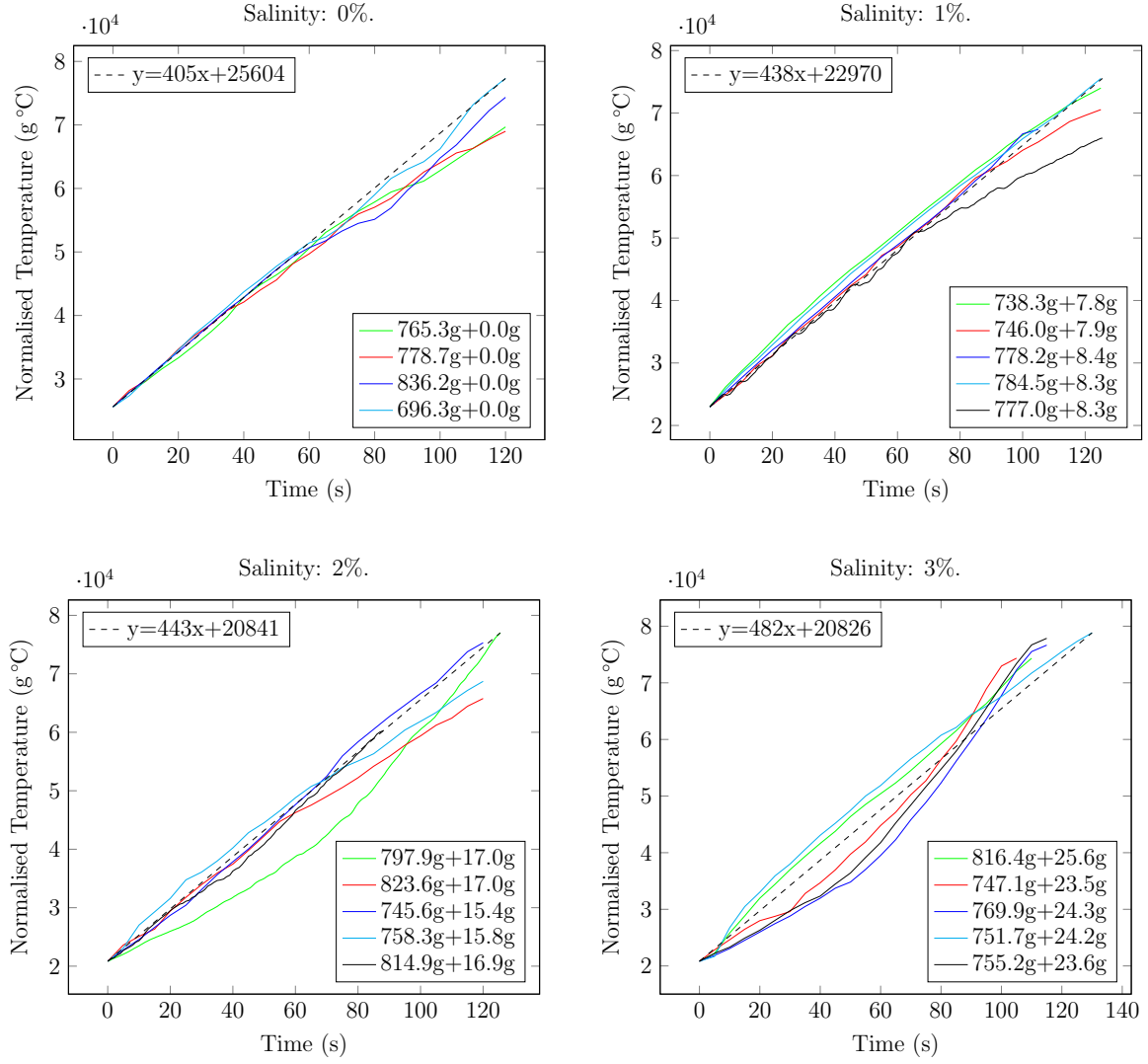


Figure 2: Processed data for each sample. The slope given is a mean value with about 5% variation. Note that legends are in the format mass of water + mass of salt.



sample to table value ( $c_t$ ):

$$e = \frac{c_t}{c} = \frac{c_t}{\frac{P}{slope}} = \frac{4.186}{4.94} = 0.85 \quad (2)$$

## 6 Conclusion

## 7 Evaluation

## References