# Evaporative Cooling of a Binary Solvent Mixture

D 1

**Aim:**

To investigate if there is a linear relationship between the mole composition of an Propanone/ethanol mixture and the degree of cooling through evaporation.

**Identification of Variables:**

Dependent variable:

- The minimum temperature reached on the probe during the evaporation.

Independent variable:

- The mole composition of the Propanone/ethanol mixture tested.

Controlled Variables:

- The amount of solvent mixture used in cooling experiment.
- The initial solvent temperature.
- The initial surface area of solvent drop being cooled.
- The surrounding air temperature.
- The amount of draught in the surrounding air.

**Materials required:**

D 2

Pure Propanone
Pure ethanol
Vernier data-logging interface and two temperature probes
Lap-top computer
Dropping pipettes
Boiling tubes and rubber bungs
Top-pan balance
Thick laboratory tissue paper
Clamp stands and clamps.

**Procedure:**

1. Place a boiling tube (balanced in a small beaker) on the top pan balance and set tare to zero.

D 2

2. Use a dropping pipette to measure about 5.00 g of Propanone into the boiling tube and quickly insert bung. Label as sample A.
3. In boiling tube B measure out about 3.50g of Propanone then re-set the tare to zero and then add about 1.50g ethanol.

D 3

4. Repeat this procedure to make a total of six samples of different compositions (A to F) finishing with pure ethanol.

D 2

5. Leave the boiling tubes to stand for 15 minutes for temperatures to reach room temperature.
6. Prepare each Vernier temperature probe by carefully cutting a 6cm x 2cm strip of the thick tissue paper in the lab. Roll the strip tightly around base of temperature probe and secure with a small amount of sellotape at the top end. Allow tape to cover the top 0.5cm of the tissue paper with 1.5cm left uncovered.
7. Plug probes into the interface and use Vernier LoggerPro software on a laptop for data collection.
8. Dip one probe into the boiling tube A and the other into boiling tube B. Quickly pull probes out and fix with a clamp. Press to start data collection on the laptop.

D 2

9. Place a large cardboard box with the top cut off over temperature probes to reduce affect of draughts.

D 3

10. Repeat step 8 for each of the sample mixtures. Carry out a repeat measurement on at least two of the mixtures.

## Data Collection:

DCP 1

| Sample Mixture | Mass Propanone (g) (+/- 0.01) | Mass Ethanol (g) (+/- 0.01) |
|---|---|---|
| A | 5.00 | 0.00 |
| B | 3.61 | 1.38 |
| C | 3.29 | 2.14 |
| D | 4.19 | 4.40 |
| E | 2.67 | 4.51 |
| F | 0.00 | 5.00 |

DCP 1

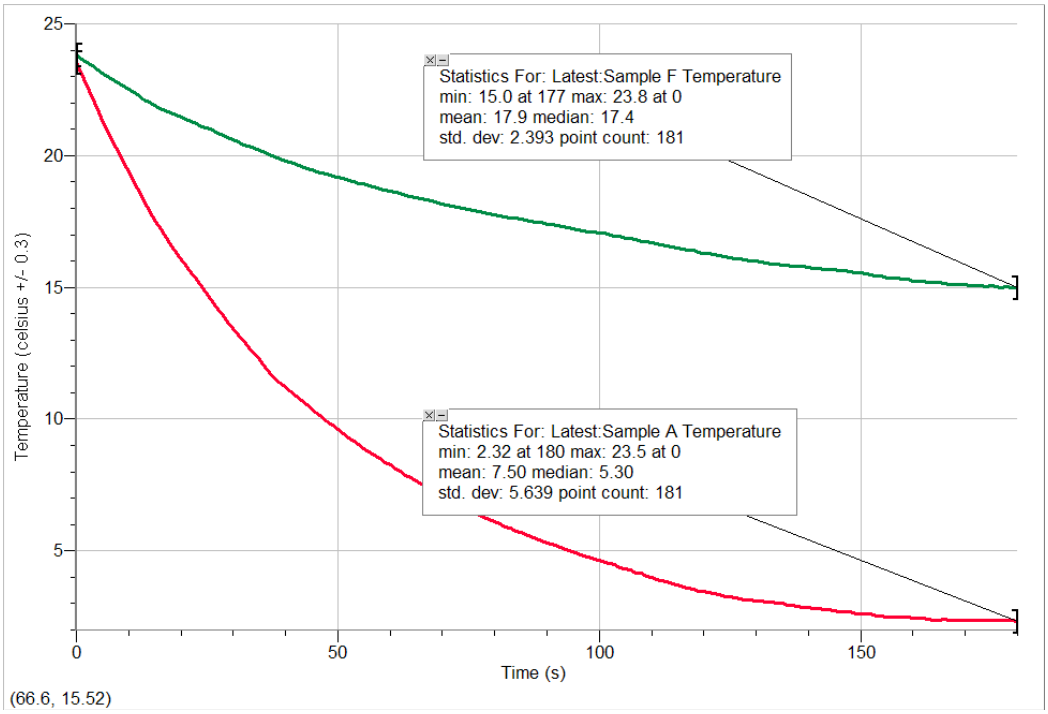
## Cooling Data:

Uncertainty in temperature probes (Vernier leaflet) = +/- 0.3 °C

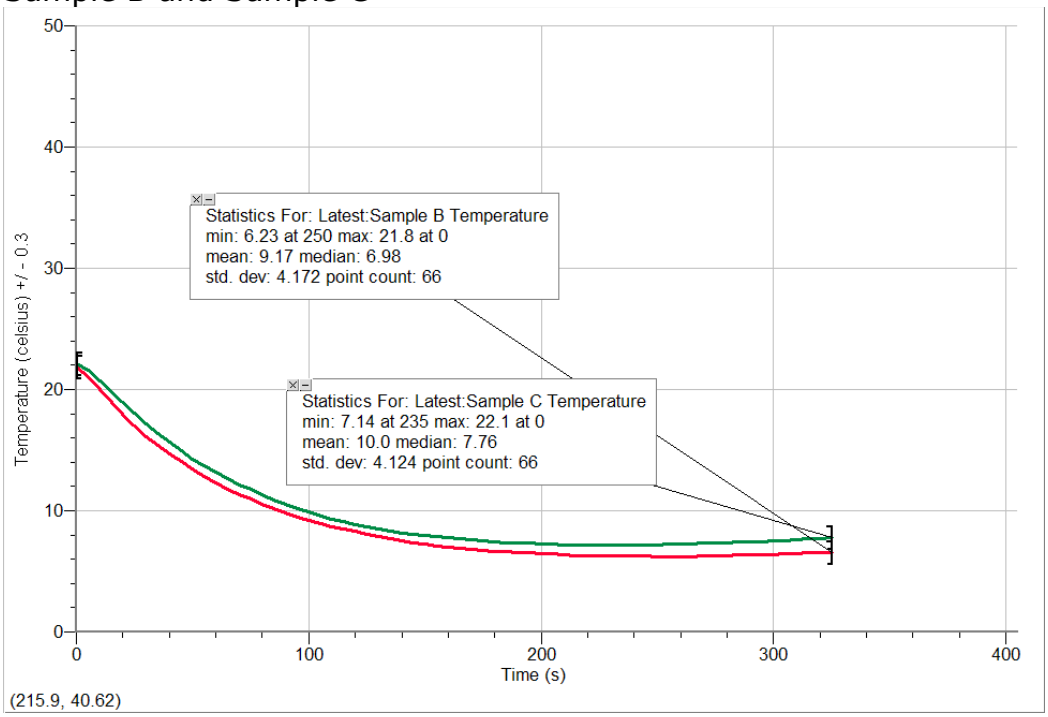
Qualitative Observations: Tissue paper still damp at the end of data collection.

Sample A & Sample F

DCP 1

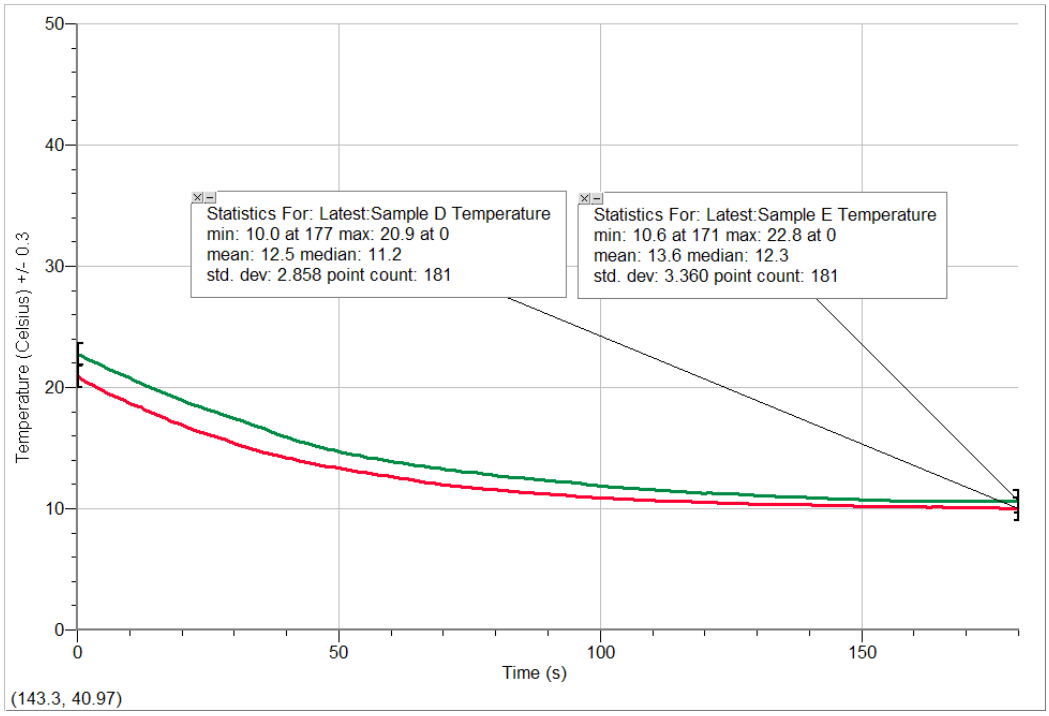



## Sample B and Sample C

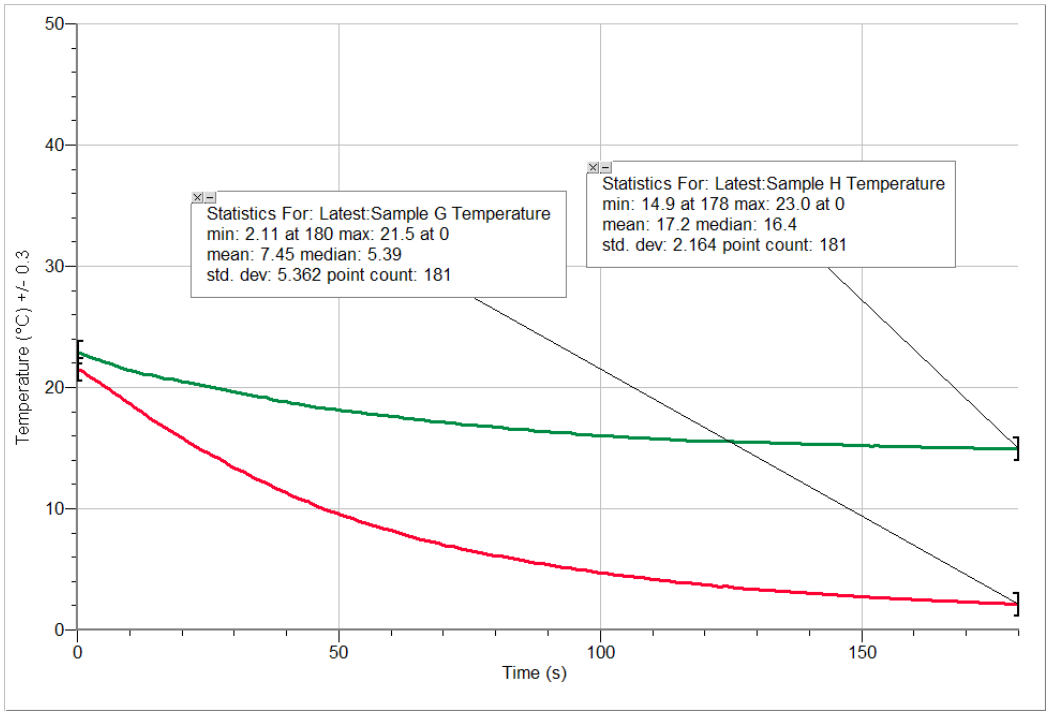



## Sample D and Sample E

DCP 1




## Sample G (A repeated) and Sample H (F repeated)



DCP 2

**Data Processing:**

Moles of Propanone = mass of propanone/Mr =mass/58

Moles of ethanol = mass of ethanol/Mr = mass/46

Mole Fraction Propanone =
mole propanone/(moles propanone+ moles etanol)

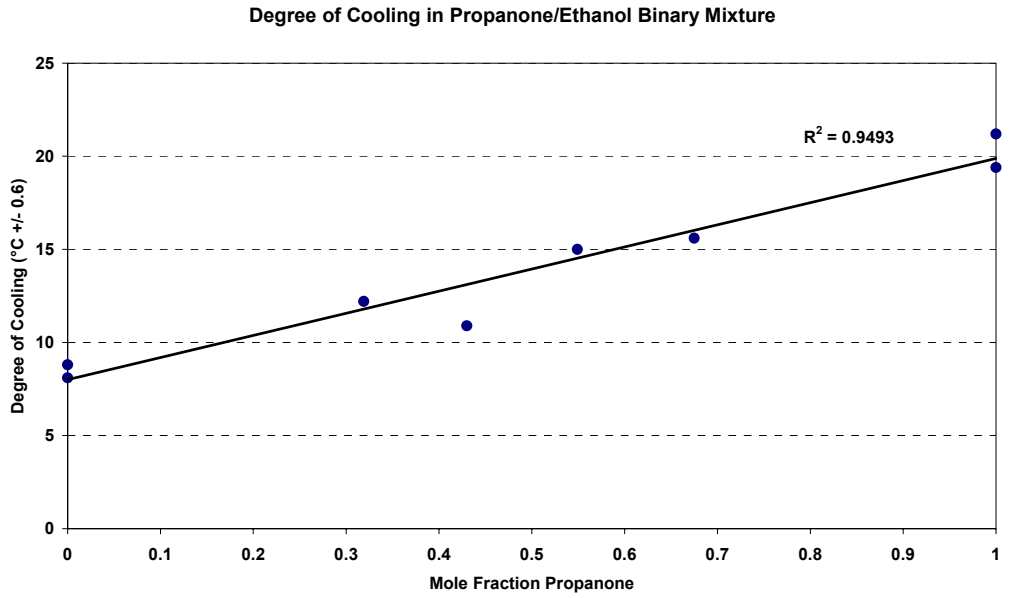
Mole Fraction Ethanol =
mole Ethanol/(moles propanone+ moles ethanol)

Degree of cooling =
Initial Temperature of sample – Minimum temperature of sample

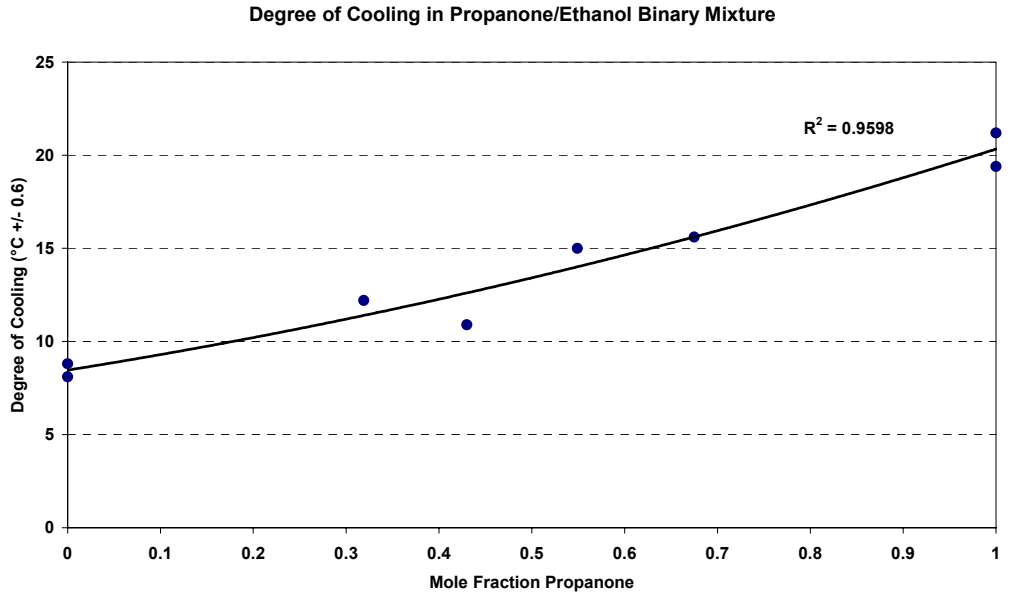
| Sample Mixture | Moles Propanone (+/- up to 0.4%) | Moles Ethanol (up to 0.7%) | Mole Fraction Propanone (up to 2%) | Mole Fraction Ethanol (up to 2%) | Degree of Cooling (°C) +/- 0.6 |
|---|---|---|---|---|---|
| A | 0.0862 | 0.0000 | 1.000 | 0.000 | 21.2 |
| B | 0.0622 | 0.0300 | 0.675 | 0.325 | 15.6 |
| C | 0.0567 | 0.0465 | 0.549 | 0.451 | 15.0 |
| D | 0.0722 | 0.0957 | 0.430 | 0.570 | 10.9 |
| E | 0.0460 | 0.0980 | 0.319 | 0.681 | 12.2 |
| F | 0.0000 | 0.1087 | 0.000 | 1.000 | 8.8 |
| A repeat | 0.0862 | 0.0000 | 1.000 | 0.000 | 19.4 |
| F repeat | 0.0000 | 0.1087 | 0.000 | 1.000 | 8.1 |

DCP 2/3

Graph 1. Molar composition v Degree of cooling with linear trendline




Graph 2. Molar composition v Degree of cooling with polynomial trendline




**Conclusion:**

CE 1

As expected the solvents showed major cooling which is due to the high energy particles evaporating through the liquid surface. The more volatile liquid propanone, which has weaker dipole-dipole intermolecular forces than the hydrogen bonding in ethanol, showed greater cooling since there is a greater proportion of particles with enough energy to break the surface and evaporate.

We can see the effect of composition of solvent mixtures in graphs 1 and 2. It appears that the relationship between molar composition and degree of evaporative cooling in the propanone/ethanol mixture is not linear and is a shallow negative curve.

The $R^2$ correlation coefficient of 0.96 is very close to the 0.95 of the linear plot. Because of the random error in plotting the points (about 2% of the molar composition and +/- 0.6 °C on the temperature scale), and because the repeat run of pure ethanol showed a difference of 1.8°C indicating some systematic error, this means that these relative correlations are too close to confidently whether the relationship is linear or not.

**Evaluation of Experimental Procedure:**

CE 2

The estimated random error does not completely explain the error which appeared when I repeated the pure ethanol measurement. So there were probably sources of systematic error.

One source of systematic error related to the data logger temperature readings. By the time I had removed the two probes from the solvent and clamped them and then pressed start on the software the temperature had already started dropping. This gave an error in the maximum temperature meaning that all values for the amount of cooling were too low. Also the data logger stopped collecting data in some trials just before the minimum temperature was reached.

These errors can be reduced by clamping probes and starting data logger before immersing them in the liquid. As the probes are gently drawn out of the solvent the software will detect the maximum temperature. If I had enough time I would have repeated all trials with a longer time setting on the software so that I would definitely have recorded the minimum temperature.

CE 2

Another source of error is that I assumed that the amount of liquid in each drop was the same. This is important because maybe a greater amount of liquid will evaporate for longer and will then allow time for more cooling to occur. Although it will be difficult to control drop size I could test whether this is an important control variable

CE 3

CE 3 by wrapping twice as much tissue paper around the probe for one sample of pure propanol so I could see if more liquid made a big difference.

CE 2 Another error is that the ethanol may not have been pure. I used the supplied stock bottle but that probably was only 95% ethanol with 5% water. This would reduce the ethanol composition in the mixture and introduce a third liquid, water, into the mixture. This

CE 3 source of error can be corrected by using 99% ethanol.

CE 2 I think other sources of system error were small. The cardboard box should have stopped draughts, I took great care in exposing the same area of tissue paper and the trials were all carried out in one lesson so room temperature should have been constant.

CE 3 The experiment would also have benefited from testing each sample more than once and also by preparing samples of more different compositions so my data points would have covered a greater range of composition values.