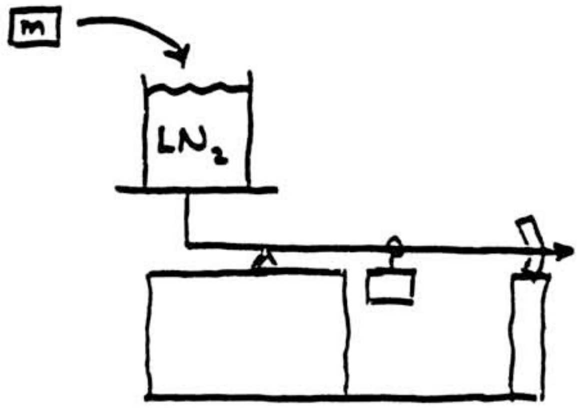
## Experimental Problem 1 -- Solutions

### Method #1

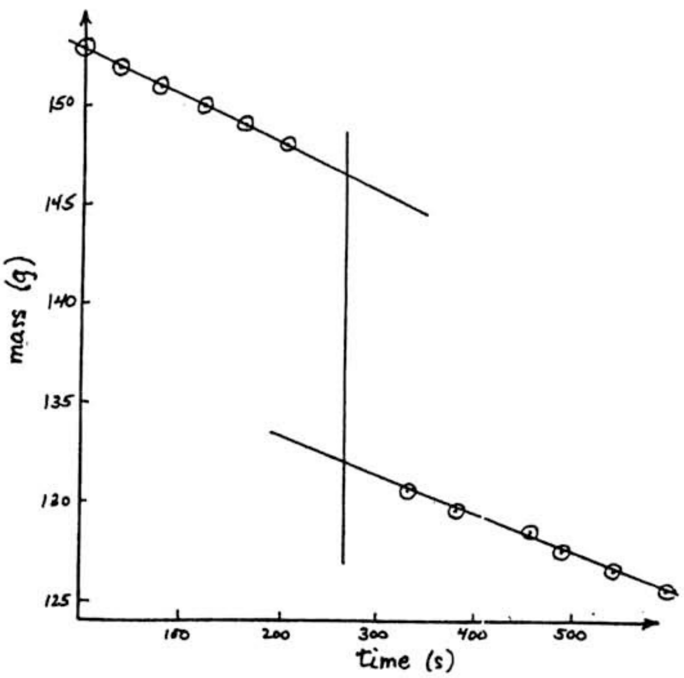



$$Q = mc\Delta T = m \int c \, dT$$

$$Q = L \, \Delta M_{LN_2}$$

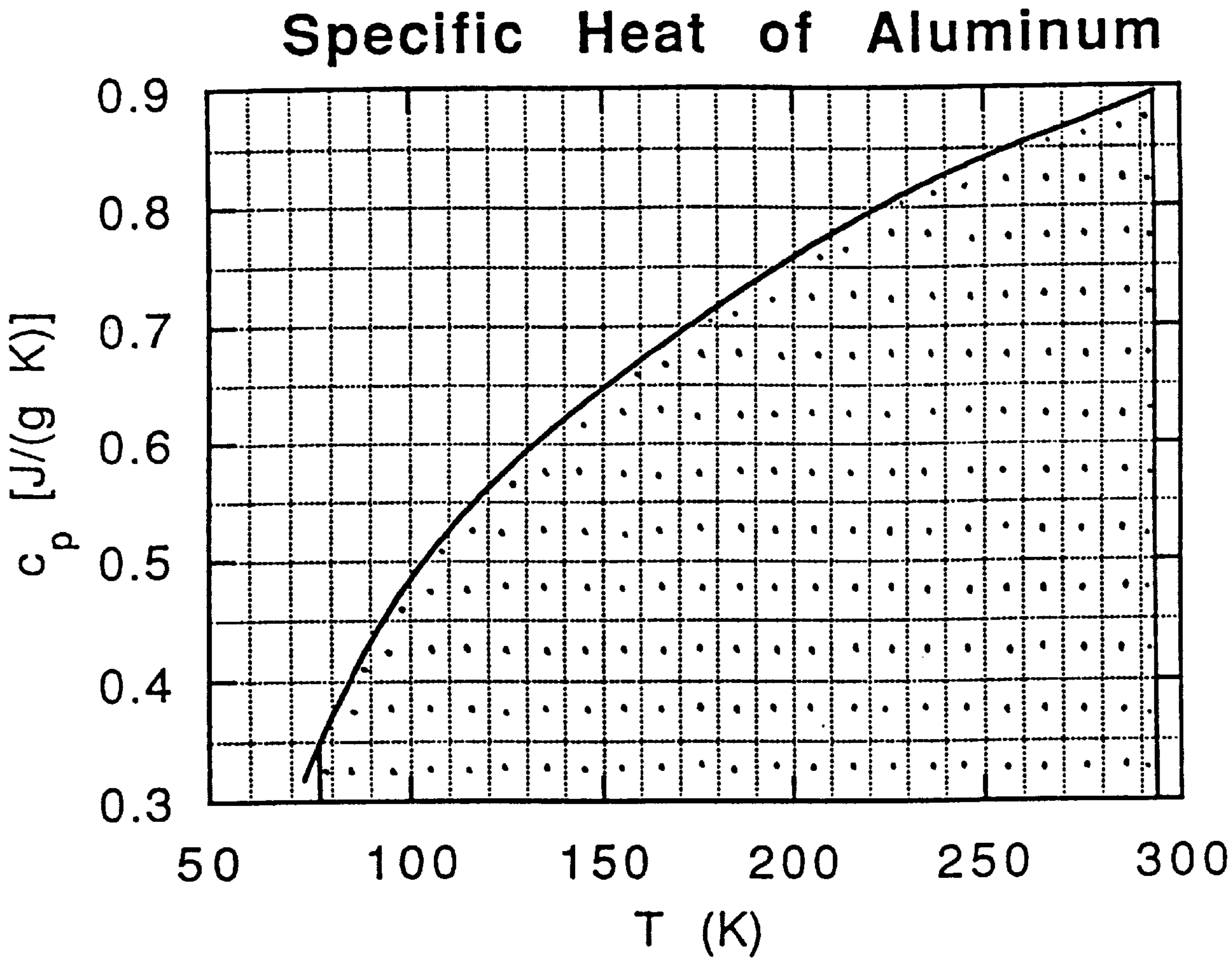
$$m = 19.4 \pm 0.1 \text{ g}$$

| | total mass | clock time | time |
|---|---|---|---|
| | 153 g | 0:00.0 | 0 |
| | 152 | 0:36.8 | 36.8 |
| | 151 | 1:19.1 | 79.1 |
| | 150 | 2:00.7 | 120.7 |
| | 149 | 2:40.5 | 160.5 |
| | 148 | 3.23.1 | 203.1 |
| Add Al mass | | | |
| | 150 (130.6) | 5:31.8 | 331.8 |
| | 149 (129.6) | 6:21.6 | 381.6 |
| | 148 (128.6) | 7:17.3 | 457.3 |
| | 147 (127.6) | 8:08.6 | 488.6 |
| | 146 (126.6) | 9:00.9 | 540.9 |
| | 145 (125.6) | 9:54.6 | 594.6 |




$$\Delta M_{LN_2} = 146.5 - 132.0$$
$$= 14.5 \pm 0.3 \text{ g}$$

Method #1 (cont'd)




$$\int_{77}^{293} c\,\mathrm{d}T \approx (0.3)(293-77) + (173)(0.5)$$

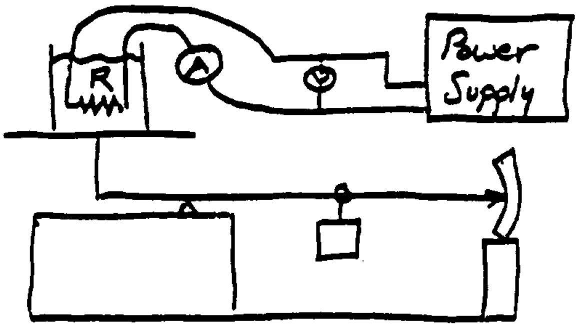
$$\approx 64.8 + 86.5 = 151 \pm 2 \text{ J/g}$$

$$Q = \int m\,c\,\mathrm{d}T = (19.4 \pm 0.1 \text{ g})(151 \pm 2 \text{ J/g})$$

$$= 2930 \pm 42 \text{ J.}$$

$$L = \frac{Q}{\Delta M_{\mathrm{LN2}}} = \frac{2930 \pm 42 \text{ J}}{14.5 \pm 0.3 \text{ g}} = 202 \pm 5 \text{ J/g}$$

## Method #2




$P = IV = V^2/R = I^2R$

$P = \Delta Q/\Delta t$

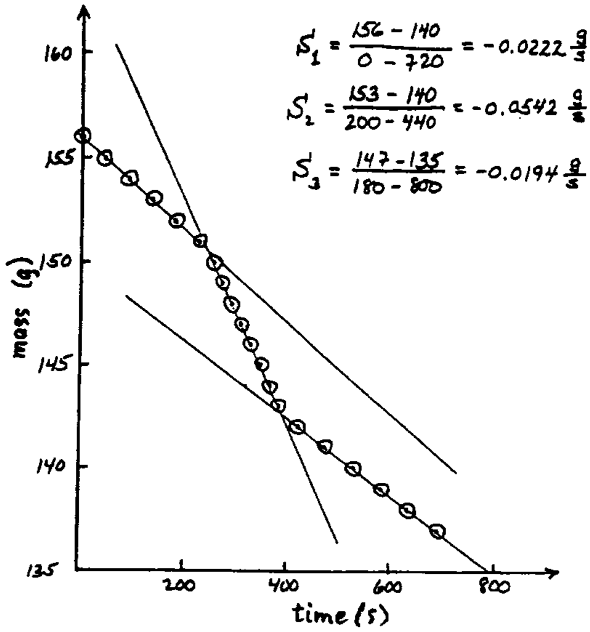
$Q = M_{LN_2}L$

$R = 23.0\ \Omega$ (in $LN_2$)

$V = 12.7$ V

$I = 0.56$ A

| | total mass | clock time | time |
|---|---|---|---|
| | 156 g | 0:00.0 | 0 s |
| | 155 | 0:45.2 | 45.2 |
| | 154 | 1:31.4 | 91.4 |
| $P = 0$ | 153 | 2:16.2 | 136.2 |
| | 152 | 2:60.0 | 180.0 |
| | 151 | 3:47.2 | 227.2 |
| | 150 | 4:13.6 | 253.6 |
| | 149 | 4:32.1 | 272.1 |
| | 148 | 4:50.1 | 290.1 |
| $P \neq 0$ | 147 | 5:08.9 | 308.9 |
| | 146 | 5:27.2 | 327.2 |
| | 145 | 5:45.7 | 345.7 |
| | 144 | 6:04.1 | 364.1 |
| | 143 | 6:21.9 | 381.9 |
| | 142 | 7:02.3 | 422.3 |
| | 141 | 7:58.4 | 478.4 |
| $P = 0$ | 140 | 8:51.2 | 531.2 |
| | 139 | 9:43.7 | 583.7 |
| | 138 | 10:34.6 | 634.6 |
| | 137 | 11:30.7 | 690.7 |




$$S_{P\neq 0} = -\,0.054 \pm 0.001 \text{ g/s}$$

$$\langle S_{P=0} \rangle = -\,0.020 \pm 0.001 \text{ g/s}$$

$$\text{Power} = P = \left|\frac{Q}{\Delta t}\right| = L\left|\frac{\Delta M_{LN2}}{\Delta t}\right|$$

$$\left.\begin{aligned} P &= IV &= 7.11\text{ W} \\ P &= I^2R &= 7.21\text{ W} \\ P &= V^2/R &= 7.01\text{ W} \end{aligned}\right\} P = 7.1 \pm 0.1\text{ W}$$

$$|\Delta M_{LN_2}/\Delta t| = 0.054 - 0.020 = 0.034 \pm 0.0014 \text{ J/s}$$

$$L = \frac{P}{\Delta M_{LN2}/\Delta t} = \frac{7.1 \pm 0.1}{0.034 \pm 0.0014} = 209 \pm 9 \text{ J/g}$$

Experimental Problem 1: Grading Scheme

Method No. 1 (5 points maximum)

1) 0.5 Uses $Q = mc\Delta T$ or $Q = m \int c\, dT$

2) 0.5. Uses $Q = L\Delta M_{LN_2}$

3) 0.5 Measures mass of aluminum correctly

4) 0.5 Measures $\Delta M_{LN_2}$ in some way

5) 0.5 Takes into account "thermal leakage" in some way and corrects for aluminum added to container

6) 0.5 Takes into account "thermal leakage" not being constant in time

7) 0.5 Uses reasonable values for $c$ and $\Delta T$ or does $\int c\, dT$ integral in a reasonable way

8) 0.5 No mistakes made in computing $L$

9) 0.5 Error estimate is reasonable for methods used

10) 0.5 Value for $L$ is within bounds set by grading team using good procedures

Method No. 2 (5 points maximum)

1) 0.5 Uses $P = \Delta Q/\Delta t$

2) 0.5 Uses $P = IV = I^2R = V^2/R$

3) 0.5 Uses $Q = LM_{LN_2}$

4) 0.5 Measures two parameters (to get $P$) correctly

5) 0.5 Measures $M_{LN_2}$ in some way

6) 0.5 Takes into account "thermal leakage" in some way

7) 0.5 Takes into account "thermal leakage" not being constant in time

8) 0.5 No mistakes made in computing $L$

9) 0.5 Error estimate is reasonable for methods used

10) 0.5 Value for $L$ is within bounds set by grading team using good procedures