北京大学
PEKING UNIVERSITY

实验一　燃烧热的测定

测量苯甲酸、蔗糖、黄冰糖燃烧过程中的热效应

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温度：25.1 °C
大气压强：100.61 kPa

关键词: 国家精品课　物理化学实验　燃烧热的测定　雷诺图解法

摘要:　本实验中，通过已知燃烧热的基准物质苯甲酸，使用雷诺校正法修正燃烧过程中氧弹的温差，测定氧弹式量热计的量热计常数 $W = (2292.0 \pm 16)\mathrm{J \cdot K^{-1}}$，进而得到蔗糖的燃烧焓 $\Delta_c H_m^{\ominus}(\mathrm{Sucrose}) = (-5631 \pm 9)\ \mathrm{kJ \cdot mol^{-1}}$、黄冰糖的燃烧焓 $\Delta_c H_m^{\ominus}() = (-5627 \pm 11)\ \mathrm{kJ \cdot mol^{-1}}$

1 引言

1.1 实验目的

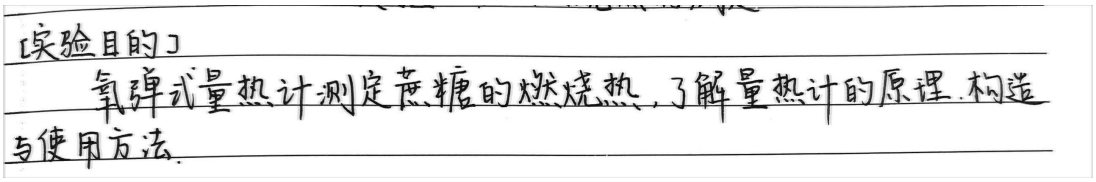

[实验目的]
氧弹式量热计测定蔗糖的燃烧热，了解量热计的原理、构造与使用方法。

图 1: 实验目的

1.2 实验原理

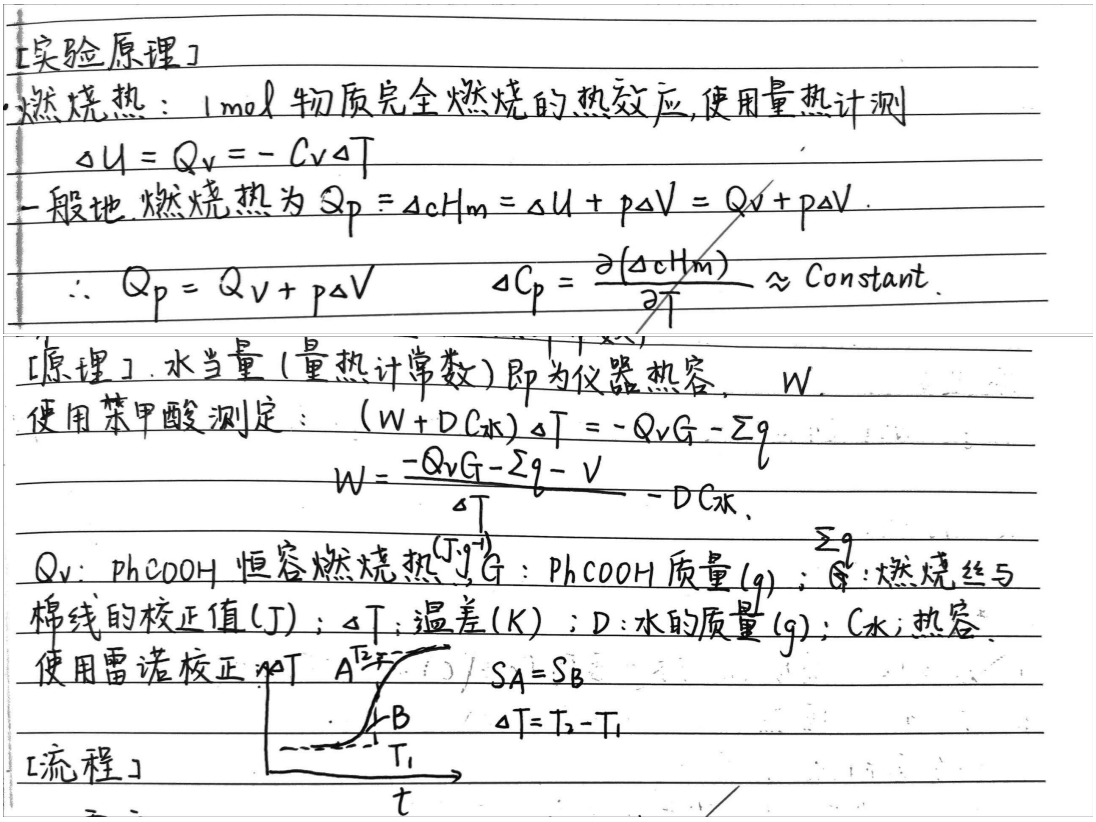

[实验原理]
燃烧热：1mol 物质完全燃烧的热效应，使用量热计测
$\Delta U = Q_V = -C_V \Delta T$
一般地，燃烧热为 $Q_p = \Delta_c H_m = \Delta U + p\Delta V = Q_V + p\Delta V$
$\therefore Q_p = Q_V + p\Delta V$ $\quad C_p = \frac{\partial(\Delta_c H_m)}{\partial T} \approx$ Constant
[原理] 水当量（量热计常数）即为仪器热容，W
使用苯甲酸测定：$(W + DC_{水})\Delta T = -Q_V G - \Sigma q$
$W = \frac{-Q_V G - \Sigma q - V}{\Delta T} - DC_{水}$
Q_V：PhCOOH 恒容燃烧热 $(J \cdot g^{-1})$；G：PhCOOH 质量(g)；Σq：燃烧丝与棉线的校正值(J)；ΔT：温差(K)；D：水的质量(g)；$C_{水}$：热容
使用雷诺校正 ΔT
$S_A = S_B$
$\Delta T = T_2 - T_1$
[流程]

图 2: 实验目的

1.3 实验方法

本次实验使用氧弹式量热计，首先，以苯甲酸为基准物质，测定苯甲酸燃烧的温度差-时间曲线，使用雷诺校正法，得到量热计常数；其次，测定蔗糖与黄冰糖的温度差-时间曲线，使用雷诺校正法，得到蔗糖与黄冰糖的燃烧焓；最终，计算所有结果的不确定度。

2 实验

2.1 主要仪器与药品

- **仪器**：氧弹式量热计，压片机，热电偶温差测量仪，容量瓶（1000 mL、2000 mL），万用表，电脑（自带），分析天平。
- **药品**：Ni 丝，棉线，蔗糖（方糖），苯甲酸（A.R.），黄冰糖，氧气（钢瓶）。

2.2 实验步骤与条件

1. 分别取约 2.0 g 方糖（蔗糖）、约 10 cm 棉线、约 5 cmNi 丝，并精确称重。
2. 将棉线系在方糖上，精确称重，再将 Ni 丝穿过棉线，最后将 Ni 丝两段分别固定在正负电极上，将电极上的螺母拧紧。
3. 组装好燃烧弹，洗气 3-5 次，最后充入约 1.1MPa 氧气。用万用表测试充气阀头与燃烧弹盖之间的电阻，一般小于 10 Ω 即为通路。
4. 将氧弹放入量热计内筒，用 1000 mL、2000 mL 准确量取 3000 mL 去离子水小心导入内筒中。
5. 盖好盖板，插入温差仪的热电偶探头，打开搅拌马达，将温差示数归零，将数据线与电脑链接，打开数据记录软件，点击“开始记录”。
6. 待温度基本稳定后，按住点火键 3 s，点燃方糖，观察到温度迅速上升。
7. 待温度再次稳定并呈现出下降趋势时，点击“停止记录”并保存数据，停止搅拌取出热电偶探头。氧弹在通风橱中排除废气后打开，取出并称量剩余 Ni 丝的精确质量。倒出内筒中的水，并将仪器上所有水渍擦干，准备下一轮实验。

按照上述方法，测量各约 1.0 g 的苯甲酸与黄冰糖的燃烧热。

3 数据处理与结果呈现

3.1 实验数据

3.1.1 燃烧物种质量的测定

本实验在投入氧弹燃烧前，精确测定了待燃烧物的质量（Ni 丝，棉线，蔗糖/苯甲酸/黄方糖）。

表 1: 待燃烧物质量的测定

燃烧样品	棉线质量 m_1	样品与棉线总质量 m_2	样品质量 m_0
蔗糖	0.0137 g	2.1055 g	2.0918 g
苯甲酸	0.0163 g	1.1256 g	1.1419 g
黄方糖	0.0173 g	0.9987 g	0.9814 g
燃烧样品	Ni 丝燃烧前质量 $m_{1,\mathrm{Ni}}$	Ni 丝燃烧后质量 $m_{2,\mathrm{Ni}}$	Ni 丝燃烧的质量 m_{Ni}
蔗糖	0.0125 g	0.0114 g	0.0011 g
苯甲酸	0.0120 g	0.0116 g	0.0004 g
黄方糖	0.0099 g	0.0080 g	0.0016 g

3.1.2 其他物理量的测定

本实验中还测定了一系列物理量，用以辅助实验顺利进行。

表 2: 其他物理量的测定

实验组别	氧气分压 $p_{\mathrm{O_2}}$	氧弹正负极电阻 R
蔗糖	1.10 MPa	4.00-5.00 Ω
苯甲酸	1.10 MPa	3.80-4.00 Ω
黄冰糖	1.10 MPa	3.00-3.60 Ω

3.1.3 体系温度差-时间关系的测定

本实验中直接测量的实验数据为体系的温度差 ΔT(K) 与时间 t(s)。分别测定了蔗糖、苯甲酸、黄冰糖的数据。由于篇幅原因，原始数据在附录中呈现。

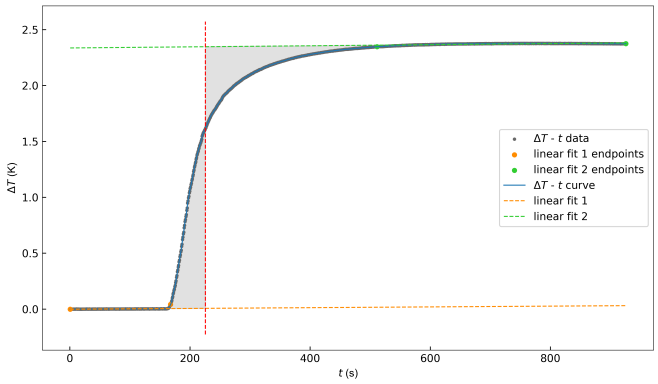
3.2 数据处理

3.2.1 温度差-时间曲线的绘制与雷诺校正

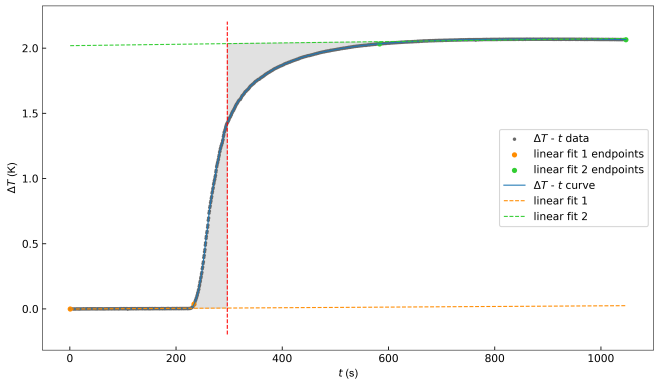
使用 ZhaoZh02（赵泽华）提供的数据处理工具 绘制蔗糖、苯甲酸、黄冰糖燃烧的温度差-时间曲线，并进行雷诺校正，得到图 3。

温度差-时间曲线中，反应前、反应后的温度平台区拟合得到的两条回归直线，其表达式如表 3。

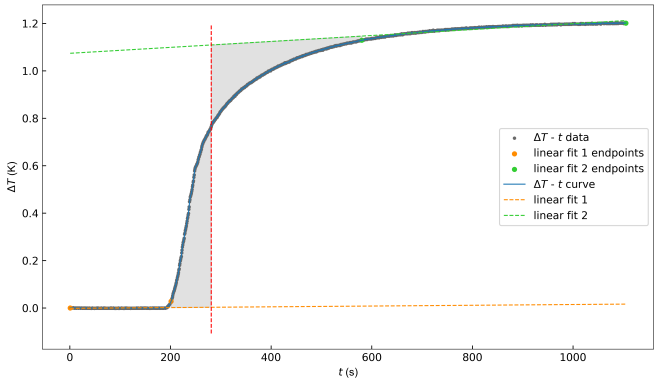
雷诺校正后，反应起始温度（T_{A}）与终止温度（T_{B}）的温度差（ΔT）如表 4。



(a) 蔗糖



(b) 苯甲酸



(c) 黄冰糖

图 3: 不同样品燃烧的温度差-时间曲线（matplotlab 绘制）

表 3: 反应前与反应后温度的回归线表达式

燃烧样品	回归直线（反应前）	
蔗糖	$\Delta T/\,\mathrm{K} = (3.427 \pm 0.481) \times 10^{-5} t/\,\mathrm{s} + (-1.282 \pm 0.467) \times 10^{-3}$	$r^2 = 0.1782$
苯甲酸	$\Delta T/\,\mathrm{K} = (2.420 \pm 0.228) \times 10^{-5} t/\,\mathrm{s} + (-1.056 \pm 0.308) \times 10^{-3}$	$r^2 = 0.2566$
黄冰糖	$\Delta T/\,\mathrm{K} = (1.637 \pm 0.320) \times 10^{-5} t/\,\mathrm{s} + (-1.790 \pm 0.370) \times 10^{-3}$	$r^2 = 0.0856$
燃烧样品	回归直线（反应后）	
蔗糖	$\Delta T/\,\mathrm{K} = (4.877 \pm 0.164) \times 10^{-5} t/\,\mathrm{s} + (2.336 \pm 0.001)$	$r^2 = 0.6027$
苯甲酸	$\Delta T/\,\mathrm{K} = (5.304 \pm 0.161) \times 10^{-5} t/\,\mathrm{s} + (2.018 \pm 0.001)$	$r^2 = 0.6252$
黄冰糖	$\Delta T/\,\mathrm{K} = (12.50 \pm 0.15) \times 10^{-5} t/\,\mathrm{s} + (1.074 \pm 0.001)$	$r^2 = 0.8990$

表 4: 雷诺校正得到的时间与反应前后的温度差

燃烧样品	t_0	T_A	T_B	ΔT
蔗糖	225.76 s	0.006 K	2.347 K	2.341 K
苯甲酸	296.55 s	0.006 K	2.034 K	2.028 K
黄冰糖	280.35 s	0.003 K	1.109 K	1.106 K

为了训练在 origin 中的绘图能力，使用以上结果，绘制了蔗糖燃烧的温度差-时间曲线并进行雷诺校正，如图 4。

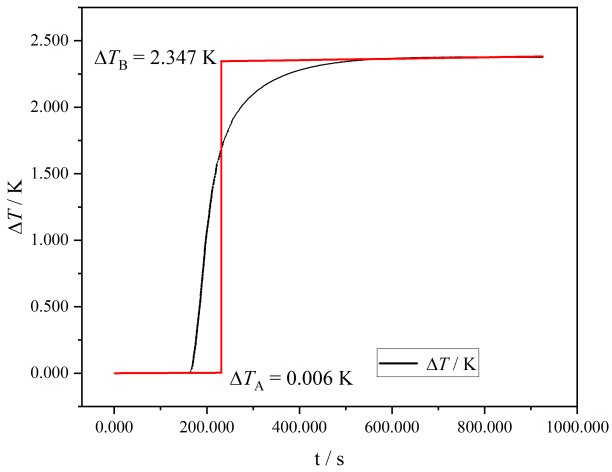


图 4: 蔗糖燃烧的温度差-时间曲线（Origin 绘制）

3.2.2 量热计常数的计算

在本实验中，将分析纯的苯甲酸作为基准物质，通过苯甲酸的燃烧求算量热计常数。

已知苯甲酸燃烧的化学反应方程式为：

$$\mathrm{C_6H_5COOH(s)} + 7.5\,\mathrm{O_2(g)} \longrightarrow 7\,\mathrm{CO_2(g)} + 3\,\mathrm{H_2O(l)} \quad \Delta_c H_m^{\ominus} = -3226.8\ \mathrm{kJ \cdot mol^{-1}}$$

反应气体的 $\Delta_n = -0.5\ \mathrm{mol}$，可求得 1 g 苯甲酸等压热效应

$$\begin{aligned} Q_{V,m} &= Q_{p,m} - \Delta nRT = \Delta_c H_m^{\ominus} - \Delta nRT \\ &= (-3226.8 - (-0.5) \times 8.314 \times 298.3 \times 10^{-3})\ \mathrm{kJ} = -3225.6\ \mathrm{kJ} \\ Q_V &= Q_{V,m} \times \frac{1\ \mathrm{g}}{M_{\mathrm{PhCOOH}}} \\ &= -3225.6 \times \frac{1}{122.12}\ \mathrm{J \cdot g^{-1}} = -26.41\ \mathrm{J \cdot g^{-1}} \end{aligned}$$

已知样品质量见表 1，校正后的温度差见表 4，可得量热计常数

$$\begin{aligned} W &= \frac{-Q_V G - \sum q}{\Delta T} - DC_{\mathrm{H_2O}} \\ &= \frac{-Q_V G - (\Delta H_{\mathrm{Ni}} m_{\mathrm{Ni}} + \Delta H_{\mathrm{cotton}} \times m_{\mathrm{cotton}})}{\Delta T} - DC_{\mathrm{H_2O}} \\ &= \left[\frac{26.41 \times 10^3 \times 1.1256 - (-3243 \times 0.0011 - 16736 \times 0.0163)}{2.028} - 3000 \times 0.997 \times 4.180\right] \mathrm{J \cdot K^{-1}} \\ &= 2.292 \times 10^3\ \mathrm{J \cdot K^{-1}} \end{aligned}$$

3.2.3 蔗糖燃烧热的计算

蔗糖燃烧的化学反应方程式为；

$$\mathrm{C_{12}H_{22}O_{11}(s)} + 12\,\mathrm{O_2(g)} \longrightarrow 12\,\mathrm{CO_2(g)} + 11\,\mathrm{H_2O(l)}$$

由此可知，蔗糖燃烧的 $\Delta n = 0$，所以

$$Q_V = Q_p = \Delta H$$

由量热计常数的计算公式，可以反推得到恒容热效应的计算式

$$\begin{aligned} W &= \frac{-Q_V G - \sum q}{\Delta T} - DC_{\mathrm{H_2O}} \\ Q_V &= -\frac{(W + DC_{\mathrm{H_2O}})\Delta T + \sum q}{G} \end{aligned}$$

已知样品质量见表 1，校正后的温度差见表 4，可得

$$\begin{aligned} Q_V &= \left[-\frac{(2.292 \times 10^3 + 3000 \times 0.997 \times 4.180) \times 2.341 + (-3243 \times 0.0004 - 16736 \times 0.0137)}{2.0918}\right] \mathrm{J \cdot g^{-1}} \\ &= -16.45\ \mathrm{kJ \cdot g^{-1}} \end{aligned}$$

$$\begin{aligned}\Delta_c H_m^{\ominus} &= Q_p M_{\text{Sucrose}} = Q_V M_{\text{Sucrose}} \\ &= -16.45 \times 342.3\ \text{kJ} \cdot \text{mol}^{-1} = -5631\ \text{kJ} \cdot \text{mol}^{-1}\end{aligned}$$

3.2.4 黄冰糖燃烧热的计算

黄冰糖是一种粗加工的蔗糖，其中含有的微量杂质与矿物质使之带有了黄色，主要成分仍然为蔗糖（> 97%）。同理蔗糖的燃烧热的计算

$$\begin{aligned}Q_V &= \left[-\frac{(2.292 \times 10^3 + 3000 \times 0.0997 \times 4.180) \times 1.106 + (-3243 \times 0.0016 - 16736 \times 0.0173)}{0.9814}\right] \text{J} \cdot \text{g}^{-1} \\ &= -16.37\ \text{kJ} \cdot \text{g}^{-1}\end{aligned}$$

$$\begin{aligned}\Delta_c H_m^{\ominus} &= Q_p M_{\text{Sucrose}} = Q_V M_{\text{Sucrose}} \\ &= -16.38 \times 342.3\ \text{kJ} \cdot \text{mol}^{-1} = -5607\ \text{kJ} \cdot \text{mol}^{-1}\end{aligned}$$

4 结果与讨论

4.1 误差分析

4.1.1 量热计常数的不确定度计算

称量误差

$$\sigma_m = \frac{e}{\sqrt{3}} = 1.2 \times 10^{-4}\ \text{g}$$
$$\sigma_{\Delta m} = \frac{2e}{\sqrt{3}} = 2.3 \times 10^{-4}\ \text{g}$$

容量瓶定容误差

$$\sigma_V = 0.1\% \times 3000\ \text{mL} = 3\ \text{mL}$$

由于热电偶温度计的仪器误差未知，所以量热计温度差不确定度，可以近似的根据回归直线的不确定度求算得到。

在最小二乘法进行的线性回归中 $y = ax + b$，预测值 $\hat{y}$ 的标准误差可以表示为

$$\sigma_{\hat{y}} = \sqrt{\sigma_a^2 \cdot x^2 + \sigma_b^2 + 2 \cdot \text{Cov}(a, b) \cdot x + \sigma^2}$$

其中，协方差 $\text{Cov}(a, b)$ 与残差 σ^2 一般较小，可以忽略，因此，我们得到

$$\sigma_{\hat{y}} = \sqrt{\sigma_a^2 \cdot x^2 + \sigma_b^2}$$

表 5: 温度差的不确定度计算

燃烧样品	σ_{T_A}	σ_{T_B}	$\sigma_{\Delta T}=\sqrt{\sigma_{T_\mathrm{A}}^2+\sigma_{T_\mathrm{B}}^2}$
蔗糖	1.2×10^{-3} K	1.1×10^{-3} K	1.6×10^{-3} K
苯甲酸	0.7×10^{-3} K	1.1×10^{-3} K	1.3×10^{-3} K
黄冰糖	1.0×10^{-4} K	1.1×10^{-3} K	1.5×10^{-3} K

将 4 中的温度带入 3 的回归直线中，得到温度及温度差的不确定度，如表 5。

根据

$$W=\frac{-Q_V G-\sum q}{\Delta T}-DC_{\mathrm{H_2O}}$$
$$\sum q=Q_{V,\mathrm{cotton}}m_{\mathrm{cotton}}+Q_{V,\mathrm{Ni}}\Delta m_{\mathrm{Ni}}$$

其中，其他热效应 $\sum q$ 的不确定度

$$\begin{aligned}\sigma_{\sum q}&=\sqrt{\left(\frac{\partial q}{\partial m_{\mathrm{cotton}}}\sigma_{m_{\mathrm{cotton}}}\right)^2+\left(\frac{\partial q}{\partial \Delta m_{\mathrm{Ni}}}\sigma_{\Delta m_{\mathrm{Ni}}}\right)^2}\\&=\sqrt{\left(Q_{V,\mathrm{cotton}}\sigma_{m_{\mathrm{cotton}}}\right)^2+\left(Q_{V,\mathrm{Ni}}\sigma_{\Delta m_{\mathrm{Ni}}}\right)^2}\end{aligned}$$

表 6: 温度差的不确定度计算

燃烧样品	其他热效应 $\sum q$	不确定度 $\sigma_{\sum q}$
蔗糖	232.8 J	2.1 J
苯甲酸	274.1 J	2.1 J
黄冰糖	284.7 J	2.1 J

首先，求量热计常数的不确定度（在不确定的度的计算过程中，为了简明起见，将不会书写单位）

$$W=-C_{\mathrm{H_2O}}V\rho_{\mathrm{H_2O}}+\frac{-GQ_V-\sum q}{\Delta T}$$
$$\begin{aligned}\frac{\partial W}{\partial G}&=-\frac{Q_V}{\Delta T}=-\frac{-26410}{2.028}=1.3\times10^4\\\frac{\partial W}{\partial \sum q}&=-\frac{1}{\Delta T}=-\frac{1}{2.028}=-0.49\\\frac{\partial W}{\partial V}&=-C_{\mathrm{H_2O}}\rho_{\mathrm{H_2O}}=-4.18\times0.997=-4.2\\\frac{\partial W}{\partial \Delta T}&=\frac{GQ_V+\sum q}{\Delta T^2}=\frac{1.1256\times(-26410)+(-274.1)}{2.028^2}=-7.3\times10^3\end{aligned}$$

$$
\begin{aligned}
\sigma_W &= \sqrt{\left(\frac{\partial W}{\partial G}\sigma_G\right)^2 + \left(\frac{\partial W}{\partial \sum q}\sigma_{\sum q}\right)^2 + \left(\frac{\partial W}{\partial V}\sigma_V\right)^2 + \left(\frac{\partial W}{\partial \Delta T}\sigma_{\Delta T}\right)^2} \\
&= \sqrt{\left(1.3\times 10^4 \times 0.00023\right)^2 + (-0.49\times 2.1)^2 + (-4.2\times 3.0)^2 + \left(-7.3\times 10^3 \times 0.0013\right)^2} \\
&= \sqrt{(3.0)^2 + (-1.0)^2 + (-13.0)^2 + (-9.5)^2} \\
&= 16 \ \mathrm{J\cdot K^{-1}}
\end{aligned}
$$

得到量热计常数可以表示为

$$
W = (2292 \pm 16) \ \ \mathrm{J\cdot K^{-1}}
$$

4.1.2 蔗糖燃烧热的不确定度计算

根据

$$
Q_V = \frac{-\Delta T\left(C_{\mathrm{H_2O}} V \rho_{\mathrm{H_2O}} + W\right) - \sum q}{G}
$$

可以求得蔗糖燃烧热效应的不确定度

$$
\begin{aligned}
\frac{\partial Q_V}{\partial W} &= -\frac{\Delta T}{G} = -\frac{(2.341)}{(2.0918)} = -1.1 \\
\frac{\partial Q_V}{\partial G} &= \frac{\Delta T\left(C_{\mathrm{H_2O}} V \rho_{\mathrm{H_2O}} + W\right) + \sum q}{G^2} \\
&= \frac{(2.341)\times((4.18)\times(3000)\times(0.997) + (2292)) + (-232.8)}{(2.0918)^2} = 7.9\times 10^3 \\
\frac{\partial Q_V}{\partial \sum q} &= -\frac{1}{G} = -\frac{1}{(2.0918)} = -0.48 \\
\frac{\partial Q_V}{\partial V} &= -\frac{C_{\mathrm{H_2O}} \Delta T \rho_{\mathrm{H_2O}}}{G} = -\frac{(4.18)\times(2.341)\times(0.997)}{(2.0918)} = -4.7 \\
\frac{\partial Q_V}{\partial \Delta T} &= \frac{-C_{\mathrm{H_2O}} V \rho_{\mathrm{H_2O}} - W}{G} = \frac{-(4.18)\times(3000)\times(0.997) - (2292)}{(2.0918)} = -7.1\times 10^3
\end{aligned}
$$

$$
\begin{aligned}
\sigma_{Q_V} &= \sqrt{\left(\frac{\partial Q_V}{\partial W}\sigma_W\right)^2 + \left(\frac{\partial Q_V}{\partial G}\sigma_G\right)^2 + \left(\frac{\partial Q_V}{\partial \sum q}\sigma_{\sum q}\right)^2 + \left(\frac{\partial Q_V}{\partial V}\sigma_V\right)^2 + \left(\frac{\partial Q_V}{\partial \Delta T}\sigma_{\Delta T}\right)^2} \\
&= \Bigg((-1.1\times 16.0)^2 + \left(7.9\times 10^3 \times 0.00023\right)^2 + (-0.48\times 2.1)^2 + (-4.7\times 3.0)^2 + \\
&\quad \left(-7.1\times 10^3 \times 0.0016\right)^2\Bigg)^{\frac{1}{2}} \\
&= \sqrt{(-18.0)^2 + (1.8)^2 + (-1.0)^2 + (-14.0)^2 + (-11.0)^2} \\
&= 25 \ \mathrm{J\cdot g^{-1}}
\end{aligned}
$$

蔗糖燃烧热可以表示为

$$
Q_V = \left(-1.645\times 10^4 \pm 25\right) \ \ \mathrm{J\cdot g^{-1}}
$$

最终，得到蔗糖的燃烧焓

$$\begin{aligned}\Delta_c H_m^{\ominus}(\text{Sucrose}) = Q_V M_{\text{Sucrose}} &= \left((-1.645 \times 10^4 \pm 25.0) \times 342.3\right)\ \text{J} \cdot \text{mol}^{-1} \\ &= (-5631 \pm 9)\ \text{kJ} \cdot \text{mol}^{-1}\end{aligned}$$

4.1.3 黄冰糖燃烧热的不确定度计算

类似地，根据

$$Q_V = \frac{-\Delta T\left(C_{\text{H}_2\text{O}} V \rho_{\text{H}_2\text{O}} + W\right) - \sum q}{G}$$

可以求得黄冰糖燃烧热效应的不确定度

$$\begin{aligned}\frac{\partial Q_V}{\partial W} &= -\frac{\Delta T}{G} = -\frac{(1.106)}{(0.9814)} = -1.1 \\ \frac{\partial Q_V}{\partial G} &= \frac{\Delta T\left(C_{\text{H}_2\text{O}} V \rho_{\text{H}_2\text{O}} + W\right) + \sum q}{G^2} \\ &= \frac{(1.106) \times ((4.18) \times (3000) \times (0.997) + (2292)) + (-232.8)}{(0.9814)^2} = 1.7 \times 10^4 \\ \frac{\partial Q_V}{\partial \sum q} &= -\frac{1}{G} = -\frac{1}{(0.9814)} = -1.0 \\ \frac{\partial Q_V}{\partial V} &= -\frac{C_{\text{H}_2\text{O}} \Delta T \rho_{\text{H}_2\text{O}}}{G} = -\frac{(4.18) \times (1.106) \times (0.997)}{(0.9814)} = -4.7 \\ \frac{\partial Q_V}{\partial \Delta T} &= \frac{-C_{\text{H}_2\text{O}} V \rho_{\text{H}_2\text{O}} - W}{G} = \frac{-(4.18) \times (3000) \times (0.997) - (2292)}{(0.9814)} = -1.5 \times 10^4\end{aligned}$$

$$\begin{aligned}\sigma_{Q_V} &= \sqrt{\left(\frac{\partial Q_V}{\partial W}\sigma_W\right)^2 + \left(\frac{\partial Q_V}{\partial G}\sigma_G\right)^2 + \left(\frac{\partial Q_V}{\partial \sum q}\sigma_{\sum q}\right)^2 + \left(\frac{\partial Q_V}{\partial V}\sigma_V\right)^2 + \left(\frac{\partial Q_V}{\partial \Delta T}\sigma_{\Delta T}\right)^2} \\ &= \sqrt{(-1.1 \times 16.0)^2 + \left(1.7 \times 10^4 \times 0.00023\right)^2 + (-1.0 \times 2.1)^2 + (-4.7 \times 3.0)^2 + \left(-1.5 \times 10^4 \times 0.0015\right)^2} \\ &= \sqrt{(-18.0)^2 + (3.9)^2 + (-2.1)^2 + (-14.0)^2 + (-23.0)^2} \\ &= 33\ \text{J} \cdot \text{g}^{-1}\end{aligned}$$

黄冰糖燃烧热可以表示为

$$Q_V = \left(-1.638 \times 10^4 \pm 33\right)\ \text{J} \cdot \text{g}^{-1}$$

假设黄冰糖中的成分全部为蔗糖，则黄冰糖的燃烧焓

$$\begin{aligned}\Delta_c H_m^{\ominus}(\text{黄冰糖}) = Q_V M_{\text{Sucrose}} &= \left((-1.638 \times 10^4 \pm 33.0) \times 342.3\right)\ \text{J} \cdot \text{mol}^{-1} \\ &= (-5607 \pm 11)\ \text{kJ} \cdot \text{mol}^{-1}\end{aligned}$$

4.1.4 蔗糖燃烧热的实验误差

查阅 CRC 手册[1]，得到

$$\Delta_c H_m^{\ominus}(\text{Sucrose}, 25^\circ\text{C}) = -5640.1\ \text{kJ} \cdot \text{mol}^{-1}$$

则相对实验误差为

$$E_r(\Delta_c H_m^{\ominus}) = \frac{(-5630) - (-5640.1)}{-5640.1} \times 100\% = -0.16\%$$

由此可见，使用氧弹式量热计测得的蔗糖燃烧热与文献标准值的误差较小，本实验的准确度很高。

4.2 思考题

4.2.1 思考题 1

- **体系**：包括放入氧弹中的样品、氧气、氧弹本身以及量热计内的固定量的水。
- **环境**：量热计外部的空气、量热计的外壳等外部环境。
- **热交换**：量热计外壳与外部环境（空气）之间的热交换。
- **热交换对结果的影响**：当体系温度等于外部环境温度时，热交换基本不会发生，对于结果没有影响；当燃烧完成后，体系温度高于外部温度，体系会释放一定热量到外部环境中，导致体系温度（水温）升高值降低，最终得到的结果偏小。
- **校正方法**：
  1. **使用量热计常数**：这是一个由标准物质（苯甲酸）标定的标准值，代表温度上升一个单位时系统吸收的热量。通过使用已知的燃烧值的标准样品来校准量热计，可以确保仪器在平行实验时的精确性。
  2. **变量的控制**：确保氧弹的密封性、样品质量的准确性、准确标定水浴中水的体积。
  3. **使用雷诺校正**：雷诺校正一定程度上可以排除热交换的影响，得到因为燃烧导致的温升值的准确值。

4.2.2 思考题 2

使用氧弹充氧时应当注意：

- **气阀的开关顺序**：充气时，先将减压阀连接至氧弹上，再打开总阀，缓慢打开减压阀控制充入氧弹的氧气气压；充气过后，先关闭总阀，再关闭减压阀。
- **压力**：氧弹压力应当控制在合理范围内，如果过高，可能导致在燃烧时气压骤增超出氧弹承受极限，发生爆炸；如果过低，可能导致实验样品不完全燃烧，降低实验的准确性。

- **充气前洗气**：为了避免空气中氮气对于反应的影响，应当在充气前洗气至少 3 次，保证空气完全被氧气代替。如果洗气不彻底，再体系点燃过程中的高温放电的条件会使得氮气与氧气发生反应生成NO_2，NO_2 又会与反应产生的水生成硝酸，这会造成实验准确性的降低。

4.2.3 思考题 3

- **搅拌过快**：搅拌过程中，搅拌器与水之间的摩擦会产生热量，如果搅拌过快，这部分热量会显著增加，进而影响实验结果。
- **搅拌过慢**：如果搅拌不充分，水浴中的水温会不均匀，导致热电偶温度计测得体系的温度会产生较大的误差，进而到时实验结果产生偏差。

4.2.4 思考题 4

此处我们不妨考虑，在本实验中，所使用的 3000 mL 水的仪器误差对于量热计常数带来的相对偏差的影响。为此，我们假定其他项的误差为 0，单独考察水体积对于量热计常数的误差，根据

$$W = -C_{\mathrm{H_2O}} V \rho_{\mathrm{H_2O}} + \frac{-GQ_V - \sum q}{\Delta T}$$

可以发现

$$\frac{\partial W}{\partial V} = -C_{\mathrm{H_2O}} \rho_{\mathrm{H_2O}} = -\left(4.18\right) \times \left(0.997\right) = -4.2$$

$$\begin{aligned} \sigma'_W &= \sqrt{\left(\frac{\partial W}{\partial V}\sigma_V\right)^2} \\ &= \sqrt{\left(-4.2 \times 3.0\right)^2} \\ &= \sqrt{\left(-13.0\right)^2} \\ &= 13 \ \mathrm{J \cdot K^{-1}} \end{aligned}$$

这十分接近量热计常数的误差 16 $\mathrm{J \cdot K^{-1}}$，由此可见，容量瓶所带来的误差在量热计常数的测定中占据了主导地位。

4.3 总结

本次实验中，同学们使用氧弹式量热计，测定了量热计的量热计常数、蔗糖与黄冰糖的燃烧热，对于量热计的原理，构造与使用方法有了全面的了解。

本次实验的结果中，测定得到的蔗糖燃烧焓 $\Delta_c H_m^{\ominus}(\mathrm{exp}) = (-5631 \pm 9)\ \mathrm{kJ \cdot mol^{-1}}$，实验标准值 $\Delta_c H_m^{\ominus}(\mathrm{exp}) = -5640\ \mathrm{kJ \cdot mol^{-1}}$ 基本落在其误差范围内，可以认为测量结果的准确性较高。

而对于黄冰糖，其燃烧热 $\Delta_c H_m^{\ominus}(\text{exp}) = (-5607 \pm 11)\ \text{kJ} \cdot \text{mol}^{-1}$ 小于蔗糖的标准燃烧焓 $\Delta_c H_m^{\ominus}(\text{exp}) = -5640\ \text{kJ} \cdot \text{mol}^{-1}$，这可能是两方面原因造成的：

- **纯度**：黄冰糖的主要成分为蔗糖（> 97%），但其中杂质的相对含量远大于实验的相对误差，这部分杂质的燃烧热低于蔗糖的燃烧热，对实验结果带来的负误差。
- **燃烧过程**：黄冰糖为结晶，其比表面积远不如疏松多孔的方糖（蔗糖）或粉末制成的苯甲酸压片，在被棉线点燃时，在被点燃前，黄冰糖受到高温可能会融化然后滴落在燃烧皿中，导致难以完全燃烧，为实验结果带来负误差。

4.4 意见与建议

- **修正的改进**：本实验中，Ni 丝在燃烧后产生 NiO，本实验中通过 Ni 丝在反应前后的质量差来判断 Ni 丝燃烧的质量，显然这是不准确的，燃烧产生的 NiO 会附着在 Ni 丝表面。因此，为了使得实验结果更为准确，可以使用一定简单的方法（如弱酸溶液）洗去 Ni 丝表面的 NiO，再进行称重。
- **样品的选择**：本实验中，自选样品可以从食用油/黄冰糖/奶片/白冰糖中任选其一，可以由以下几点改进方向：
  - 食用油为液体，不利于充分燃烧，因此，可以使用一些熔点较高的固体油脂（如松香等）进行实验。
  - 实验样品可以不局限于给定的食品样品，也可以让同学们自己带一些感兴趣的食品样品进行燃烧热的测定。

5 附录

表 7: 蔗糖燃烧热的测定

t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K
0.643	5.140	186.000	5.667	371.524	7.383	556.860	7.499	742.349	7.517
1.283	5.139	186.794	5.701	372.159	7.384	557.641	7.499	742.985	7.516
2.063	5.140	187.431	5.719	372.941	7.386	558.276	7.500	743.763	7.516
2.706	5.140	188.209	5.762	373.578	7.386	559.062	7.500	744.405	7.517
3.485	5.139	188.851	5.783	374.353	7.388	559.709	7.500	745.187	7.516
4.123	5.140	189.629	5.813	375.005	7.389	560.486	7.500	745.824	7.517
4.905	5.140	190.268	5.828	375.773	7.390	561.126	7.501	746.602	7.517
5.558	5.140	191.050	5.868	376.425	7.391	561.907	7.500	747.245	7.517
6.337	5.140	191.686	5.889	377.204	7.392	562.548	7.501	748.022	7.517
6.980	5.140	192.466	5.923	377.846	7.392	563.324	7.500	748.660	7.517

7.757	5.140	193.109	5.940	378.624	7.394	563.959	7.501	749.443	7.516
8.399	5.140	193.900	5.968	379.267	7.395	564.751	7.501	750.086	7.516
9.172	5.140	194.537	5.985	380.050	7.396	565.392	7.502	750.865	7.517
9.814	5.140	195.316	6.024	380.681	7.396	566.172	7.501	751.508	7.517
10.593	5.140	195.958	6.044	381.462	7.397	566.803	7.502	752.282	7.517
11.237	5.141	196.734	6.089	382.105	7.397	567.595	7.501	752.924	7.517
12.014	5.141	197.367	6.107	382.882	7.399	568.220	7.501	753.718	7.517
12.652	5.140	198.156	6.136	383.520	7.400	569.007	7.502	754.345	7.516
13.434	5.140	198.796	6.149	384.303	7.400	569.648	7.502	755.130	7.517
14.083	5.141	199.575	6.180	384.944	7.401	570.429	7.502	755.767	7.517
14.866	5.140	200.219	6.195	385.722	7.403	571.069	7.502	756.550	7.517
15.494	5.140	201.011	6.219	386.361	7.403	571.857	7.503	757.195	7.517
16.273	5.140	201.641	6.230	387.144	7.405	572.486	7.503	757.972	7.517
16.922	5.140	202.425	6.253	387.782	7.405	573.278	7.503	758.614	7.516
17.700	5.139	203.075	6.266	388.575	7.405	573.909	7.503	759.393	7.517
18.339	5.140	203.853	6.292	389.202	7.405	574.690	7.502	760.035	7.517
19.126	5.140	204.491	6.304	389.981	7.406	575.333	7.504	760.813	7.517
19.764	5.140	205.275	6.330	390.624	7.408	576.112	7.503	761.455	7.517
20.542	5.139	205.911	6.343	391.403	7.408	576.749	7.504	762.239	7.516
21.185	5.140	206.689	6.370	392.041	7.409	577.531	7.503	762.876	7.517
21.955	5.140	207.332	6.384	392.825	7.410	578.169	7.503	763.659	7.516
22.608	5.140	208.105	6.410	393.463	7.410	578.947	7.504	764.297	7.516
23.387	5.140	208.758	6.424	394.251	7.411	579.590	7.504	765.072	7.517
24.028	5.140	209.536	6.446	394.889	7.411	580.369	7.504	765.713	7.516
24.799	5.140	210.179	6.457	395.668	7.412	581.021	7.504	766.492	7.516
25.438	5.140	210.951	6.481	396.311	7.414	581.800	7.504	767.131	7.517
26.222	5.140	211.588	6.494	397.089	7.414	582.440	7.504	767.923	7.517
26.863	5.140	212.378	6.518	397.726	7.415	583.208	7.504	768.550	7.517
27.642	5.141	213.022	6.529	398.520	7.415	583.856	7.505	769.332	7.516
28.285	5.141	213.801	6.545	399.147	7.416	584.640	7.504	769.984	7.517
29.063	5.140	214.433	6.554	399.940	7.417	585.284	7.505	770.752	7.517
29.704	5.141	215.211	6.573	400.578	7.418	586.061	7.505	771.405	7.517
30.482	5.140	215.864	6.583	401.362	7.419	586.702	7.505	772.175	7.516
31.125	5.140	216.642	6.602	401.993	7.419	587.473	7.506	772.817	7.516
31.903	5.140	217.285	6.609	402.775	7.420	588.112	7.505	773.600	7.517
32.541	5.141	218.064	6.623	403.414	7.420	588.893	7.506	774.239	7.517

33.325	5.141	218.701	6.631	404.196	7.421	589.541	7.505	775.016	7.517
33.962	5.140	219.484	6.647	404.839	7.422	590.320	7.506	775.669	7.516
34.756	5.140	220.122	6.659	405.621	7.423	590.964	7.505	776.449	7.517
35.383	5.140	220.899	6.686	406.256	7.424	591.747	7.506	777.081	7.516
36.177	5.140	221.542	6.697	407.045	7.424	592.374	7.506	777.870	7.517
36.814	5.140	222.320	6.711	407.683	7.425	593.168	7.507	778.497	7.517
37.592	5.140	222.957	6.718	408.460	7.425	593.804	7.506	779.278	7.517
38.236	5.140	223.740	6.727	409.097	7.426	594.582	7.506	779.919	7.517
39.013	5.141	224.381	6.732	409.886	7.427	595.226	7.506	780.706	7.517
39.651	5.140	225.157	6.741	410.523	7.427	596.008	7.507	781.338	7.517
40.434	5.140	225.804	6.746	411.299	7.428	596.635	7.506	782.133	7.516
41.078	5.141	226.590	6.757	411.942	7.428	597.422	7.506	782.759	7.517
41.850	5.140	227.225	6.763	412.714	7.428	598.061	7.506	783.553	7.517
42.498	5.140	228.002	6.778	413.360	7.429	598.844	7.506	784.193	7.517
43.273	5.141	228.648	6.785	414.137	7.431	599.482	7.507	784.975	7.517
43.918	5.140	229.424	6.797	414.779	7.431	600.268	7.507	785.612	7.516
44.694	5.140	230.071	6.803	415.555	7.432	600.909	7.507	786.381	7.517
45.338	5.140	230.841	6.815	416.197	7.432	601.687	7.508	787.023	7.517
46.123	5.140	231.486	6.820	416.985	7.432	602.332	7.507	787.808	7.517
46.762	5.141	232.262	6.833	417.621	7.433	603.109	7.508	788.446	7.517
47.536	5.141	232.909	6.839	418.397	7.435	603.745	7.507	789.225	7.517
48.181	5.141	233.682	6.850	419.050	7.435	604.524	7.508	789.872	7.516
48.957	5.140	234.320	6.854	419.831	7.435	605.175	7.508	790.650	7.516
49.598	5.141	235.115	6.864	420.464	7.436	605.941	7.508	791.294	7.517
50.375	5.141	235.740	6.870	421.241	7.436	606.587	7.508	792.078	7.516
51.022	5.140	236.534	6.880	421.893	7.437	607.366	7.508	792.715	7.516
51.803	5.140	237.172	6.884	422.659	7.437	608.017	7.508	793.494	7.517
52.435	5.141	237.949	6.893	423.300	7.438	608.784	7.508	794.128	7.516
53.227	5.141	238.596	6.896	424.082	7.439	609.426	7.509	794.921	7.517
53.858	5.140	239.376	6.904	424.723	7.440	610.205	7.508	795.558	7.517
54.644	5.140	240.013	6.909	425.504	7.441	610.847	7.509	796.337	7.516
55.280	5.141	240.796	6.917	426.141	7.441	611.626	7.509	796.978	7.517
56.061	5.140	241.434	6.920	426.933	7.442	612.270	7.509	797.753	7.517
56.702	5.141	242.213	6.926	427.563	7.442	613.058	7.509	798.399	7.517
57.483	5.141	242.855	6.931	428.345	7.442	613.691	7.509	799.181	7.517
58.119	5.140	243.638	6.939	428.996	7.443	614.471	7.509	799.818	7.517

58.910	5.141	244.277	6.943	429.776	7.443	615.117	7.509	800.596	7.516
59.536	5.141	245.055	6.952	430.402	7.444	615.896	7.509	801.240	7.516
60.329	5.141	245.696	6.955	431.199	7.445	616.539	7.508	802.017	7.516
60.959	5.140	246.475	6.965	431.825	7.445	617.316	7.509	802.655	7.516
61.744	5.142	247.122	6.969	432.618	7.446	617.962	7.510	803.434	7.516
62.385	5.141	247.889	6.976	433.253	7.447	618.734	7.510	804.076	7.517
63.161	5.141	248.541	6.980	434.036	7.446	619.376	7.510	804.854	7.516
63.812	5.141	249.321	6.987	434.673	7.447	620.160	7.510	805.491	7.516
64.583	5.140	249.963	6.991	435.452	7.448	620.796	7.510	806.281	7.516
65.232	5.141	250.742	6.999	436.095	7.448	621.574	7.510	806.918	7.517
66.007	5.140	251.380	7.003	436.878	7.448	622.222	7.510	807.702	7.516
66.642	5.141	252.154	7.008	437.515	7.448	623.000	7.510	808.345	7.516
67.434	5.141	252.796	7.012	438.299	7.449	623.638	7.510	809.123	7.516
68.064	5.141	253.574	7.019	438.931	7.450	624.427	7.509	809.760	7.516
68.845	5.141	254.226	7.026	439.710	7.450	625.064	7.510	810.544	7.517
69.487	5.141	254.993	7.036	440.349	7.451	625.842	7.511	811.186	7.516
70.278	5.141	255.636	7.041	441.131	7.453	626.485	7.510	811.969	7.516
70.913	5.141	256.416	7.048	441.784	7.452	627.255	7.510	812.609	7.516
71.691	5.141	257.065	7.051	442.558	7.453	627.898	7.510	813.377	7.516
72.327	5.141	257.843	7.056	443.190	7.452	628.677	7.511	814.015	7.516
73.107	5.141	258.481	7.058	443.982	7.454	629.325	7.511	814.798	7.517
73.754	5.141	259.261	7.063	444.620	7.454	630.104	7.511	815.440	7.516
74.528	5.141	259.907	7.066	445.399	7.454	630.741	7.511	816.224	7.517
75.173	5.141	260.687	7.070	446.041	7.454	631.523	7.511	816.862	7.517
75.951	5.141	261.325	7.072	446.819	7.456	632.162	7.511	817.643	7.517
76.588	5.141	262.104	7.077	447.457	7.455	632.940	7.511	818.286	7.516
77.372	5.140	262.742	7.080	448.240	7.457	633.577	7.511	819.064	7.516
78.013	5.141	263.524	7.085	448.877	7.457	634.365	7.511	819.701	7.516
78.792	5.141	264.168	7.089	449.655	7.458	635.002	7.511	820.485	7.516
79.430	5.141	264.951	7.094	450.298	7.458	635.781	7.511	821.123	7.516
80.213	5.141	265.589	7.096	451.076	7.458	636.424	7.511	821.901	7.516
80.850	5.141	266.367	7.101	451.729	7.458	637.203	7.511	822.549	7.516
81.639	5.141	267.008	7.103	452.508	7.459	637.839	7.511	823.327	7.516
82.271	5.141	267.787	7.107	453.135	7.459	638.628	7.511	823.965	7.516
83.050	5.140	268.425	7.109	453.929	7.460	639.271	7.511	824.744	7.517
83.702	5.141	269.208	7.113	454.567	7.460	640.049	7.512	825.386	7.516

84.480	5.141	269.845	7.115	455.350	7.460	640.686	7.511	826.164	7.516
85.123	5.141	270.624	7.120	455.987	7.461	641.469	7.511	826.816	7.516
85.901	5.141	271.272	7.123	456.765	7.462	642.107	7.512	827.593	7.516
86.531	5.141	272.043	7.128	457.408	7.462	642.891	7.511	828.231	7.516
87.318	5.141	272.681	7.131	458.186	7.463	643.534	7.512	829.009	7.516
87.955	5.141	273.471	7.136	458.827	7.463	644.308	7.512	829.651	7.516
88.734	5.141	274.108	7.138	459.605	7.464	644.944	7.512	830.429	7.517
89.376	5.141	274.886	7.142	460.249	7.464	645.732	7.512	831.067	7.516
90.159	5.141	275.524	7.144	461.026	7.464	646.368	7.512	831.851	7.516
90.797	5.141	276.307	7.149	461.669	7.464	647.155	7.512	832.500	7.516
91.590	5.141	276.951	7.150	462.445	7.465	647.792	7.513	833.279	7.517
92.222	5.141	277.730	7.155	463.082	7.465	648.576	7.512	833.916	7.516
93.000	5.142	278.372	7.157	463.870	7.465	649.212	7.512	834.699	7.516
93.638	5.141	279.151	7.161	464.512	7.466	649.997	7.512	835.337	7.517
94.422	5.141	279.788	7.162	465.295	7.466	650.634	7.513	836.121	7.516
95.060	5.141	280.581	7.165	465.932	7.467	651.421	7.513	836.762	7.516
95.838	5.142	281.208	7.167	466.710	7.467	652.046	7.513	837.537	7.516
96.486	5.141	282.002	7.171	467.353	7.467	652.835	7.513	838.175	7.516
97.262	5.141	282.639	7.173	468.132	7.467	653.471	7.513	838.958	7.516
97.899	5.141	283.423	7.177	468.769	7.468	654.258	7.513	839.600	7.516
98.692	5.141	284.061	7.178	469.552	7.468	654.888	7.512	840.379	7.516
99.326	5.141	284.838	7.183	470.192	7.468	655.682	7.513	841.021	7.516
100.111	5.141	285.481	7.184	470.971	7.469	656.308	7.513	841.804	7.516
100.748	5.142	286.251	7.188	471.614	7.469	657.102	7.513	842.440	7.516
101.530	5.141	286.897	7.190	472.400	7.470	657.740	7.512	843.219	7.516
102.169	5.141	287.681	7.194	473.038	7.470	658.520	7.513	843.860	7.516
102.953	5.141	288.333	7.196	473.817	7.471	659.159	7.513	844.642	7.516
103.595	5.141	289.117	7.200	474.459	7.471	659.941	7.513	845.281	7.516
104.374	5.141	289.754	7.202	475.243	7.471	660.584	7.513	846.058	7.516
105.011	5.141	290.537	7.205	475.869	7.472	661.353	7.513	846.699	7.516
105.790	5.141	291.175	7.207	476.652	7.472	662.001	7.514	847.478	7.515
106.432	5.141	291.957	7.209	477.302	7.472	662.780	7.514	848.117	7.515
107.211	5.141	292.599	7.211	478.071	7.473	663.427	7.514	848.904	7.516
107.847	5.141	293.379	7.213	478.712	7.473	664.205	7.513	849.541	7.516
108.630	5.142	294.016	7.214	479.506	7.473	664.846	7.513	850.329	7.516
109.267	5.141	294.794	7.218	480.145	7.473	665.628	7.514	850.955	7.516

110.061	5.142	295.437	7.220	480.927	7.474	666.256	7.514	851.750	7.516
110.692	5.141	296.216	7.222	481.554	7.474	667.049	7.513	852.388	7.516
111.471	5.142	296.856	7.224	482.334	7.474	667.685	7.514	853.171	7.516
112.107	5.142	297.639	7.228	482.986	7.475	668.464	7.514	853.797	7.516
112.889	5.141	298.276	7.228	483.754	7.475	669.107	7.514	854.591	7.516
113.539	5.142	299.056	7.232	484.407	7.475	669.884	7.514	855.218	7.516
114.318	5.142	299.697	7.233	485.177	7.476	670.522	7.514	856.000	7.516
114.955	5.142	300.476	7.236	485.824	7.476	671.301	7.514	856.653	7.515
115.740	5.141	301.114	7.238	486.602	7.476	671.939	7.514	857.422	7.516
116.383	5.141	301.906	7.240	487.240	7.477	672.733	7.514	858.068	7.516
117.162	5.141	302.534	7.243	488.017	7.478	673.372	7.514	858.846	7.516
117.803	5.141	303.313	7.245	488.659	7.477	674.146	7.513	859.485	7.516
118.582	5.142	303.966	7.247	489.444	7.478	674.783	7.514	860.269	7.516
119.221	5.142	304.733	7.248	490.080	7.477	675.562	7.514	860.905	7.515
120.006	5.141	305.386	7.250	490.866	7.478	676.210	7.514	861.683	7.515
120.639	5.142	306.165	7.253	491.506	7.478	676.992	7.515	862.322	7.516
121.418	5.142	306.803	7.255	492.290	7.480	677.630	7.514	863.105	7.516
122.055	5.142	307.582	7.258	492.932	7.479	678.413	7.514	863.742	7.516
122.838	5.142	308.219	7.260	493.710	7.479	679.055	7.515	864.536	7.515
123.476	5.141	308.996	7.263	494.349	7.480	679.833	7.514	865.163	7.516
124.255	5.142	309.638	7.264	495.128	7.480	680.476	7.514	865.956	7.516
124.897	5.141	310.417	7.266	495.759	7.480	681.250	7.515	866.594	7.516
125.680	5.142	311.055	7.267	496.552	7.481	681.894	7.515	867.375	7.515
126.318	5.142	311.847	7.269	497.183	7.481	682.677	7.514	868.011	7.515
127.103	5.142	312.484	7.270	497.965	7.481	683.311	7.515	868.790	7.515
127.735	5.142	313.271	7.274	498.603	7.482	684.089	7.515	869.427	7.515
128.530	5.142	313.898	7.275	499.383	7.482	684.726	7.515	870.210	7.515
129.168	5.142	314.692	7.277	500.024	7.482	685.520	7.514	870.847	7.515
129.950	5.142	315.319	7.278	500.818	7.483	686.153	7.515	871.642	7.516
130.588	5.142	316.112	7.282	501.456	7.483	686.930	7.515	872.266	7.515
131.367	5.142	316.738	7.282	502.236	7.483	687.573	7.514	873.060	7.515
131.999	5.142	317.522	7.284	502.877	7.483	688.357	7.515	873.697	7.516
132.782	5.141	318.160	7.284	503.657	7.484	688.994	7.515	874.476	7.515
133.421	5.141	318.942	7.286	504.295	7.484	689.772	7.515	875.118	7.516
134.211	5.142	319.585	7.288	505.078	7.484	690.407	7.515	875.896	7.515
134.841	5.142	320.364	7.290	505.715	7.484	691.191	7.515	876.540	7.515

135.621	5.142	321.006	7.291	506.494	7.485	691.828	7.516	877.313	7.515
136.264	5.142	321.789	7.295	507.127	7.485	692.622	7.515	877.950	7.515
137.047	5.142	322.434	7.296	507.909	7.486	693.249	7.515	878.745	7.515
137.691	5.142	323.217	7.298	508.547	7.486	694.043	7.516	879.371	7.515
138.468	5.143	323.854	7.300	509.340	7.486	694.680	7.515	880.165	7.515
139.113	5.142	324.638	7.302	509.982	7.486	695.463	7.515	880.803	7.515
139.890	5.142	325.276	7.303	510.761	7.486	696.184	7.515	881.585	7.515
140.533	5.142	326.059	7.305	511.398	7.485	696.884	7.515	882.218	7.516
141.312	5.142	326.696	7.306	512.175	7.487	697.520	7.515	882.996	7.515
141.958	5.142	327.481	7.308	512.818	7.487	698.306	7.516	883.633	7.515
142.737	5.141	328.108	7.309	513.597	7.487	698.941	7.515	884.416	7.515
143.375	5.142	328.901	7.311	514.240	7.487	699.714	7.515	885.056	7.515
144.159	5.142	329.539	7.312	515.017	7.488	700.360	7.515	885.835	7.515
144.787	5.143	330.308	7.313	515.654	7.489	701.145	7.515	886.477	7.515
145.571	5.143	330.947	7.315	516.433	7.488	701.781	7.515	887.267	7.515
146.214	5.142	331.728	7.317	517.081	7.488	702.567	7.514	887.904	7.515
146.988	5.142	332.367	7.318	517.859	7.489	703.206	7.515	888.687	7.515
147.626	5.142	333.150	7.321	518.499	7.489	703.988	7.516	889.330	7.514
148.410	5.142	333.803	7.322	519.282	7.489	704.625	7.515	890.110	7.515
149.052	5.141	334.581	7.322	519.919	7.489	705.405	7.515	890.747	7.515
149.830	5.142	335.209	7.324	520.697	7.489	706.047	7.515	891.529	7.515
150.472	5.142	335.993	7.325	521.340	7.490	706.826	7.516	892.157	7.515
151.256	5.142	336.630	7.326	522.118	7.489	707.468	7.516	892.950	7.515
151.897	5.143	337.423	7.328	522.755	7.490	708.247	7.516	893.592	7.514
152.681	5.143	338.060	7.329	523.549	7.491	708.884	7.516	894.371	7.515
153.309	5.143	338.838	7.331	524.182	7.490	709.672	7.516	895.008	7.515
154.094	5.142	339.475	7.331	524.964	7.491	710.311	7.516	895.791	7.515
154.731	5.142	340.259	7.334	525.602	7.491	711.094	7.516	896.428	7.514
155.515	5.142	340.896	7.334	526.385	7.492	711.725	7.516	897.206	7.515
156.153	5.143	341.674	7.336	527.026	7.491	712.502	7.516	897.937	7.515
156.947	5.143	342.325	7.337	527.804	7.492	713.147	7.516	898.626	7.515
157.583	5.142	343.104	7.339	528.446	7.492	713.924	7.516	899.264	7.515
158.366	5.143	343.739	7.339	529.232	7.492	714.568	7.516	900.043	7.514
159.003	5.142	344.523	7.341	529.866	7.492	715.348	7.516	900.685	7.514
159.781	5.142	345.165	7.342	530.651	7.493	715.989	7.516	901.463	7.515
160.423	5.142	345.943	7.344	531.290	7.493	716.774	7.516	902.117	7.515

161.202	5.142	346.590	7.345	532.076	7.493	717.412	7.516	902.894	7.515
161.839	5.143	347.358	7.347	532.709	7.493	718.191	7.516	903.613	7.514
162.626	5.143	348.000	7.347	533.494	7.493	718.832	7.516	904.305	7.515
163.264	5.144	348.779	7.348	534.128	7.493	719.610	7.516	904.957	7.514
164.042	5.145	349.428	7.349	534.913	7.493	720.255	7.516	905.732	7.514
164.683	5.146	350.207	7.351	535.551	7.494	721.036	7.516	906.370	7.514
165.466	5.152	350.851	7.352	536.328	7.494	721.679	7.516	907.155	7.514
166.105	5.156	351.633	7.353	536.970	7.494	722.458	7.516	907.796	7.515
166.887	5.165	352.262	7.354	537.745	7.495	723.096	7.516	908.580	7.515
167.520	5.171	353.040	7.356	538.391	7.494	723.878	7.516	909.213	7.514
168.304	5.182	353.691	7.357	539.172	7.495	724.510	7.516	909.999	7.514
168.941	5.187	354.464	7.358	539.803	7.495	725.289	7.517	910.636	7.514
169.747	5.204	355.107	7.359	540.594	7.496	725.930	7.517	911.418	7.514
170.384	5.215	355.885	7.360	541.230	7.495	726.723	7.517	912.052	7.514
171.162	5.239	356.528	7.361	542.017	7.496	727.352	7.516	912.835	7.514
171.798	5.250	357.307	7.362	542.658	7.495	728.136	7.516	913.480	7.514
172.582	5.275	357.945	7.363	543.434	7.496	728.776	7.516	914.257	7.514
173.221	5.286	358.738	7.364	544.075	7.496	729.555	7.516	914.899	7.514
173.998	5.307	359.369	7.365	544.861	7.496	730.198	7.516	915.682	7.514
174.640	5.318	360.153	7.367	545.487	7.497	730.985	7.517	916.319	7.514
175.419	5.340	360.796	7.367	546.279	7.496	731.625	7.516	917.107	7.514
176.056	5.352	361.578	7.369	546.909	7.497	732.399	7.516	917.732	7.513
176.851	5.377	362.218	7.370	547.690	7.497	733.045	7.516	918.524	7.514
177.478	5.393	362.999	7.372	548.342	7.497	733.826	7.516	919.156	7.514
178.258	5.424	363.626	7.372	549.122	7.498	734.452	7.516	919.935	7.514
178.899	5.440	364.410	7.374	549.758	7.498	735.244	7.516	920.577	7.514
179.693	5.474	365.048	7.375	550.539	7.497	735.879	7.517	921.357	7.514
180.331	5.489	365.830	7.376	551.175	7.498	736.662	7.516	921.998	7.514
181.110	5.516	366.469	7.377	551.951	7.498	737.297	7.517	922.783	7.515
181.740	5.531	367.248	7.378	552.598	7.499	738.085	7.516	923.418	7.514
182.521	5.563	367.890	7.379	553.375	7.499	738.729	7.516	924.199	7.514
183.159	5.578	368.683	7.380	554.026	7.499	739.507	7.517	924.919	7.514
183.941	5.609	369.311	7.381	554.796	7.500	740.140	7.517	925.623	7.515
184.594	5.624	370.104	7.382	555.438	7.499	740.918	7.517	926.263	7.515
185.374	5.653	370.730	7.383	556.229	7.499	741.561	7.516		

表 8: 量热计常数的测定

t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K
0.783	-0.001	210.232	0.003	419.837	1.903	629.297	2.046	838.892	2.067
1.421	0.000	211.015	0.002	420.479	1.904	630.085	2.047	839.531	2.067
2.198	-0.001	211.649	0.003	421.263	1.905	630.721	2.047	840.308	2.068
2.840	-0.001	212.427	0.003	421.900	1.906	631.493	2.048	840.949	2.068
3.618	0.000	213.080	0.003	422.678	1.907	632.140	2.047	841.731	2.068
4.255	0.000	213.847	0.002	423.320	1.908	632.922	2.048	842.374	2.068
5.038	0.000	214.487	0.003	424.097	1.909	633.552	2.048	843.141	2.068
5.677	0.000	215.271	0.003	424.736	1.910	634.338	2.047	843.784	2.068
6.455	-0.001	215.907	0.003	425.520	1.911	634.976	2.047	844.567	2.067
7.096	-0.001	216.702	0.002	426.165	1.912	635.758	2.049	845.209	2.068
7.879	-0.001	217.340	0.003	426.937	1.914	636.404	2.048	845.986	2.068
8.518	-0.001	218.122	0.003	427.583	1.914	637.180	2.048	846.625	2.068
9.296	0.000	218.748	0.003	428.364	1.916	637.826	2.049	847.412	2.068
9.935	-0.001	219.543	0.003	428.995	1.916	638.608	2.048	848.054	2.068
10.719	-0.001	220.182	0.003	429.787	1.917	639.234	2.048	848.833	2.068
11.357	-0.001	220.955	0.003	430.412	1.917	640.022	2.049	849.472	2.068
12.145	0.000	221.600	0.002	431.194	1.920	640.662	2.049	850.255	2.068
12.782	0.000	222.378	0.002	431.841	1.920	641.444	2.049	850.891	2.068
13.569	0.000	223.020	0.003	432.622	1.922	642.075	2.049	851.664	2.067
14.208	0.000	223.799	0.003	433.254	1.922	642.871	2.049	852.306	2.067
14.982	0.000	224.444	0.003	434.040	1.924	643.507	2.049	853.085	2.068
15.625	-0.001	225.222	0.003	434.686	1.925	644.288	2.050	853.730	2.067
16.401	0.000	225.864	0.004	435.467	1.926	644.919	2.049	854.517	2.068
17.051	0.000	226.643	0.004	436.098	1.927	645.701	2.050	855.151	2.068
17.828	-0.001	227.285	0.004	436.889	1.928	646.350	2.050	855.939	2.068
18.464	0.000	228.067	0.006	437.530	1.928	647.131	2.050	856.565	2.068
19.245	-0.001	228.705	0.007	438.296	1.930	647.761	2.050	857.357	2.068
19.891	0.000	229.484	0.010	438.947	1.930	648.542	2.051	857.988	2.067
20.661	0.000	230.126	0.012	439.729	1.932	649.184	2.051	858.770	2.068
21.313	0.000	230.902	0.016	440.370	1.933	649.966	2.051	859.415	2.068
22.085	0.000	231.546	0.018	441.142	1.933	650.602	2.051	860.191	2.069
22.726	0.000	232.327	0.024	441.787	1.934	651.383	2.051	860.838	2.069
23.508	0.000	232.952	0.027	442.563	1.935	652.018	2.051	861.609	2.068
24.153	0.000	233.747	0.036	443.204	1.936	652.810	2.051	862.255	2.068

24.935	0.000	234.377	0.040	443.986	1.936	653.451	2.051	863.042	2.068
25.563	0.001	235.164	0.050	444.631	1.937	654.232	2.052	863.672	2.068
26.349	0.000	235.797	0.056	445.414	1.938	654.873	2.052	864.459	2.068
26.995	0.000	236.576	0.066	446.055	1.939	655.643	2.052	865.090	2.068
27.771	0.000	237.219	0.071	446.835	1.940	656.287	2.052	865.876	2.068
28.402	0.000	237.996	0.082	447.477	1.941	657.065	2.051	866.517	2.069
29.194	0.000	238.634	0.087	448.253	1.942	657.703	2.052	867.298	2.068
29.824	0.000	239.427	0.101	448.894	1.942	658.481	2.052	867.933	2.068
30.611	0.001	240.069	0.107	449.685	1.943	659.123	2.053	868.719	2.068
31.251	0.000	240.836	0.121	450.327	1.943	659.916	2.053	869.359	2.068
32.023	0.000	241.489	0.128	451.104	1.943	660.545	2.053	870.141	2.068
32.663	0.001	242.262	0.144	451.744	1.944	661.324	2.053	870.771	2.068
33.444	0.000	242.899	0.151	452.521	1.945	661.965	2.053	871.551	2.068
34.175	0.001	243.688	0.172	453.167	1.945	662.750	2.052	872.197	2.068
34.869	0.000	244.330	0.184	453.938	1.947	663.388	2.053	872.984	2.069
35.509	0.000	245.108	0.204	454.573	1.947	664.171	2.053	873.624	2.068
36.295	0.000	245.745	0.214	455.354	1.948	664.808	2.054	874.406	2.068
36.927	0.000	246.529	0.236	456.000	1.949	665.587	2.055	875.037	2.068
37.708	0.001	247.172	0.247	456.782	1.950	666.230	2.054	875.817	2.068
38.349	0.000	247.939	0.268	457.423	1.950	667.007	2.054	876.458	2.068
39.131	0.001	248.593	0.280	458.204	1.951	667.650	2.055	877.234	2.068
39.770	0.001	249.361	0.308	458.835	1.952	668.428	2.054	877.886	2.068
40.559	0.001	250.013	0.321	459.627	1.953	669.070	2.054	878.662	2.068
41.199	0.001	250.792	0.347	460.258	1.954	669.849	2.055	879.303	2.068
41.971	0.000	251.419	0.361	461.045	1.955	670.488	2.055	880.085	2.068
42.612	0.001	252.214	0.394	461.686	1.956	671.275	2.055	880.725	2.068
43.400	0.001	252.855	0.410	462.467	1.956	671.912	2.054	881.501	2.068
44.030	0.001	253.626	0.438	463.102	1.957	672.691	2.054	882.147	2.068
44.818	0.001	254.269	0.455	463.878	1.957	673.329	2.055	882.925	2.068
45.457	0.000	255.047	0.489	464.530	1.958	674.122	2.055	883.560	2.068
46.237	0.001	255.685	0.507	465.300	1.959	674.755	2.056	884.347	2.068
46.876	0.001	256.473	0.541	465.941	1.961	675.542	2.056	884.982	2.068
47.658	0.001	257.110	0.556	466.718	1.961	676.174	2.056	885.765	2.068
48.295	0.000	257.888	0.583	467.364	1.961	676.958	2.056	886.395	2.069
49.077	0.001	258.532	0.595	468.151	1.962	677.601	2.056	887.186	2.068
49.720	0.000	259.310	0.626	468.792	1.963	678.465	2.057	887.827	2.068

50.504	0.000	259.947	0.643	469.568	1.964	679.104	2.056	888.609	2.068
51.142	0.000	260.731	0.680	470.198	1.964	679.803	2.056	889.246	2.068
51.911	0.001	261.363	0.697	470.985	1.965	680.440	2.056	890.028	2.069
52.554	0.000	262.147	0.734	471.621	1.965	681.224	2.056	890.667	2.068
53.333	0.001	262.784	0.750	472.407	1.966	681.850	2.056	891.445	2.068
53.974	0.001	263.567	0.777	473.054	1.967	682.644	2.057	892.086	2.068
54.759	0.001	264.210	0.790	473.830	1.967	683.276	2.057	892.870	2.068
55.396	0.001	264.988	0.815	474.460	1.968	684.060	2.057	893.509	2.068
56.174	0.001	265.628	0.827	475.252	1.969	684.695	2.057	894.293	2.069
56.822	0.000	266.411	0.849	475.895	1.969	685.479	2.056	894.928	2.069
57.600	0.001	267.049	0.862	476.661	1.970	686.121	2.057	895.709	2.068
58.236	0.001	267.832	0.888	477.313	1.971	686.906	2.057	896.338	2.068
59.028	0.000	268.470	0.900	478.091	1.971	687.545	2.058	897.120	2.068
59.666	0.001	269.248	0.920	478.729	1.971	688.314	2.058	897.764	2.068
60.445	0.001	269.900	0.930	479.513	1.972	688.963	2.058	898.543	2.068
61.072	0.001	270.690	0.955	480.151	1.973	689.747	2.057	899.185	2.068
61.857	0.000	271.329	0.966	480.935	1.974	690.385	2.058	899.962	2.068
62.495	0.000	272.107	0.984	481.562	1.974	691.168	2.058	900.605	2.068
63.289	0.000	272.749	0.994	482.358	1.976	691.889	2.058	901.389	2.069
63.914	0.000	273.519	1.012	482.995	1.975	692.585	2.058	902.031	2.068
64.709	0.001	274.161	1.024	483.778	1.976	693.302	2.058	902.814	2.068
65.347	0.000	274.949	1.049	484.416	1.977	694.001	2.059	903.451	2.068
66.120	0.000	275.580	1.063	485.195	1.978	694.728	2.058	904.234	2.068
66.758	0.000	276.375	1.089	485.831	1.977	695.425	2.058	904.871	2.068
67.538	0.001	277.011	1.100	486.605	1.978	696.068	2.059	905.650	2.068
68.180	0.001	277.794	1.116	487.258	1.978	696.847	2.059	906.282	2.068
68.957	0.001	278.432	1.125	488.035	1.979	697.476	2.059	907.075	2.068
69.602	0.001	279.211	1.141	488.678	1.979	698.261	2.058	907.703	2.069
70.380	0.001	279.848	1.148	489.456	1.981	698.904	2.058	908.487	2.068
71.022	0.001	280.629	1.168	490.100	1.980	699.682	2.059	909.123	2.068
71.802	0.001	281.271	1.180	490.871	1.983	700.321	2.059	909.917	2.067
72.439	0.000	282.053	1.202	491.514	1.982	701.106	2.059	910.550	2.068
73.219	0.001	282.686	1.210	492.298	1.983	701.821	2.058	911.334	2.068
73.871	0.001	283.471	1.227	492.934	1.983	702.530	2.059	911.965	2.067
74.639	0.001	284.112	1.236	493.718	1.984	703.157	2.059	912.746	2.068
75.281	0.001	284.890	1.250	494.352	1.984	703.941	2.060	913.382	2.067

76.060	0.001	285.528	1.256	495.133	1.985	704.591	2.060	914.174	2.068
76.704	0.001	286.306	1.267	495.779	1.985	705.359	2.060	914.809	2.068
77.487	0.001	286.947	1.273	496.553	1.986	706.094	2.060	915.593	2.068
78.128	0.001	287.725	1.290	497.195	1.986	706.792	2.060	916.238	2.067
78.906	0.000	288.368	1.299	497.970	1.987	707.427	2.060	917.006	2.068
79.545	0.001	289.157	1.322	498.623	1.987	708.212	2.059	917.653	2.068
80.327	0.001	289.793	1.335	499.393	1.988	708.851	2.060	918.436	2.069
80.968	0.001	290.577	1.354	500.029	1.988	709.629	2.060	919.073	2.068
81.752	0.001	291.219	1.359	500.811	1.989	710.272	2.060	919.851	2.068
82.394	0.001	291.996	1.371	501.452	1.989	711.045	2.060	920.494	2.067
83.173	0.001	292.635	1.379	502.233	1.990	711.691	2.060	921.272	2.068
83.810	0.001	293.412	1.392	502.884	1.991	712.473	2.060	921.909	2.068
84.589	0.000	294.055	1.400	503.660	1.991	713.106	2.060	922.693	2.068
85.231	0.001	294.834	1.413	504.301	1.992	713.884	2.061	923.330	2.067
86.010	0.001	295.468	1.418	505.078	1.992	714.522	2.061	924.108	2.068
86.648	0.001	296.251	1.426	505.723	1.993	715.304	2.060	924.750	2.067
87.431	0.001	296.893	1.429	506.496	1.992	715.946	2.061	925.530	2.067
88.067	0.001	297.672	1.436	507.131	1.993	716.724	2.061	926.167	2.068
88.846	0.001	298.314	1.439	507.912	1.994	717.362	2.061	926.960	2.068
89.489	0.001	299.096	1.448	508.564	1.995	718.145	2.061	927.587	2.068
90.267	0.001	299.734	1.453	509.333	1.995	718.782	2.061	928.382	2.068
90.910	0.001	300.509	1.463	509.985	1.996	719.576	2.061	929.019	2.068
91.689	0.000	301.152	1.467	510.767	1.997	720.211	2.061	929.803	2.068
92.331	0.000	301.930	1.472	511.393	1.997	720.996	2.061	930.440	2.068
93.109	0.001	302.575	1.476	512.173	1.997	721.627	2.061	931.220	2.068
93.753	0.001	303.362	1.484	512.819	1.997	722.417	2.061	931.853	2.068
94.536	0.002	303.989	1.488	513.601	1.998	723.055	2.061	932.641	2.068
95.173	0.002	304.785	1.499	514.242	1.999	723.837	2.062	933.282	2.067
95.955	0.001	305.412	1.503	515.020	2.000	724.477	2.062	934.053	2.068
96.599	0.001	306.205	1.512	515.657	2.000	725.257	2.062	934.693	2.067
97.377	0.002	306.832	1.515	516.438	2.000	725.897	2.062	935.485	2.068
98.015	0.002	307.617	1.521	517.088	2.000	726.669	2.061	936.116	2.068
98.802	0.001	308.258	1.523	517.865	2.000	727.309	2.061	936.902	2.068
99.432	0.001	309.043	1.531	518.506	2.001	728.099	2.062	937.538	2.068
100.209	0.001	309.672	1.535	519.276	2.002	728.725	2.062	938.319	2.067
100.855	0.002	310.459	1.543	519.924	2.002	729.520	2.062	938.955	2.068

101.638	0.001	311.101	1.547	520.707	2.003	730.159	2.062	939.747	2.068
102.279	0.002	311.880	1.556	521.335	2.003	730.927	2.062	940.378	2.067
103.050	0.001	312.524	1.561	522.123	2.003	731.578	2.062	941.158	2.068
103.691	0.002	313.308	1.567	522.764	2.004	732.360	2.063	941.804	2.067
104.483	0.001	313.945	1.570	523.545	2.005	732.987	2.062	942.586	2.068
105.119	0.001	314.729	1.575	524.185	2.005	733.781	2.063	943.305	2.067
105.900	0.002	315.356	1.577	524.972	2.006	734.413	2.062	944.003	2.068
106.541	0.002	316.134	1.585	525.597	2.007	735.201	2.063	944.639	2.068
107.323	0.002	316.787	1.589	526.384	2.006	735.840	2.062	945.422	2.068
107.961	0.002	317.555	1.595	527.030	2.007	736.621	2.064	946.057	2.068
108.745	-0.002	318.209	1.598	527.807	2.007	737.261	2.063	946.849	2.067
109.383	0.001	318.986	1.602	528.437	2.007	738.037	2.063	947.484	2.068
110.151	0.001	319.618	1.604	529.229	2.008	738.677	2.063	948.255	2.068
110.801	0.001	320.397	1.606	529.861	2.008	739.462	2.063	948.901	2.068
111.581	0.001	321.042	1.607	530.646	2.008	740.102	2.063	949.677	2.068
112.218	0.001	321.821	1.614	531.288	2.009	740.874	2.064	950.319	2.068
113.006	0.001	322.463	1.617	532.075	2.010	741.517	2.063	951.110	2.068
113.643	0.002	323.242	1.625	532.707	2.009	742.291	2.063	951.746	2.067
114.422	0.001	323.879	1.630	533.483	2.010	742.931	2.063	952.522	2.067
115.064	0.001	324.668	1.636	534.129	2.011	743.715	2.063	953.167	2.067
115.843	0.002	325.306	1.637	534.910	2.012	744.358	2.064	953.939	2.067
116.480	0.002	326.090	1.641	535.550	2.012	745.132	2.064	954.575	2.068
117.258	0.001	326.717	1.644	536.332	2.012	745.771	2.063	955.362	2.067
117.895	0.002	327.511	1.649	536.963	2.012	746.558	2.063	956.004	2.067
118.674	0.002	328.138	1.651	537.744	2.013	747.197	2.064	956.786	2.067
119.328	0.001	328.931	1.657	538.386	2.013	747.985	2.063	957.416	2.067
120.094	0.001	329.565	1.661	539.162	2.014	748.620	2.063	958.207	2.068
120.739	0.002	330.345	1.666	539.813	2.014	749.402	2.064	958.839	2.068
121.519	0.002	330.989	1.667	540.594	2.015	750.036	2.065	959.630	2.068
122.161	0.002	331.773	1.669	541.235	2.014	750.820	2.064	960.265	2.068
122.938	0.002	332.411	1.672	542.006	2.015	751.456	2.064	961.052	2.067
123.581	0.001	333.190	1.677	542.647	2.015	752.241	2.065	961.688	2.067
124.360	0.002	333.832	1.678	543.429	2.016	752.877	2.064	962.459	2.067
125.001	0.001	334.610	1.681	544.075	2.016	753.667	2.064	963.105	2.068
125.781	0.001	335.248	1.684	544.856	2.016	754.299	2.064	963.882	2.067
126.427	0.001	336.025	1.687	545.492	2.017	755.076	2.065	964.522	2.067

127.203	0.002	336.672	1.689	546.274	2.017	755.725	2.064	965.304	2.067
127.849	0.002	337.450	1.695	546.910	2.017	756.507	2.064	965.951	2.067
128.630	0.002	338.087	1.697	547.690	2.018	757.145	2.064	966.724	2.067
129.260	0.001	338.871	1.702	548.329	2.018	757.923	2.064	967.371	2.067
130.046	0.002	339.510	1.705	549.106	2.019	758.566	2.064	968.142	2.067
130.683	0.002	340.288	1.709	549.749	2.018	759.334	2.065	968.784	2.068
131.464	0.002	340.926	1.711	550.529	2.019	759.986	2.064	969.565	2.066
132.099	0.002	341.710	1.714	551.171	2.019	760.761	2.065	970.202	2.067
132.891	0.002	342.348	1.716	551.950	2.020	761.398	2.064	970.989	2.067
133.521	0.002	343.126	1.719	552.589	2.020	762.177	2.064	971.629	2.067
134.307	0.002	343.768	1.722	553.367	2.021	762.825	2.065	972.411	2.068
134.953	0.002	344.547	1.724	554.009	2.021	763.598	2.065	973.042	2.068
135.727	0.002	345.184	1.726	554.796	2.021	764.241	2.061	973.828	2.066
136.372	0.001	345.972	1.729	555.433	2.021	765.024	2.065	974.476	2.067
137.145	0.002	346.614	1.731	556.218	2.022	765.668	2.065	975.256	2.067
137.792	0.002	347.393	1.736	556.859	2.021	766.447	2.065	975.895	2.067
138.574	0.002	348.034	1.738	557.638	2.021	767.083	2.065	976.676	2.067
139.214	0.002	348.813	1.742	558.276	2.022	767.866	2.065	977.316	2.067
139.986	0.002	349.449	1.744	559.058	2.022	768.505	2.064	978.087	2.067
140.634	0.001	350.227	1.746	559.702	2.023	769.283	2.065	978.728	2.067
141.404	0.001	350.878	1.747	560.480	2.024	769.925	2.064	979.504	2.067
142.051	0.002	351.657	1.749	561.110	2.024	770.710	2.065	980.151	2.067
142.827	0.002	352.295	1.751	561.895	2.024	771.338	2.065	980.937	2.067
143.472	0.001	353.077	1.754	562.536	2.025	772.121	2.065	981.576	2.067
144.248	0.002	353.708	1.756	563.319	2.025	772.758	2.065	982.358	2.068
144.895	0.002	354.500	1.759	563.955	2.024	773.551	2.065	982.993	2.067
145.670	0.002	355.135	1.760	564.734	2.025	774.189	2.065	983.766	2.067
146.311	0.002	355.911	1.761	565.372	2.025	774.971	2.065	984.419	2.067
147.098	0.002	356.549	1.761	566.160	2.027	775.611	2.065	985.198	2.067
147.727	0.001	357.330	1.764	566.798	2.026	776.394	2.065	985.840	2.067
148.505	0.002	357.970	1.766	567.577	2.027	777.021	2.065	986.619	2.067
149.151	0.002	358.763	1.770	568.224	2.027	777.800	2.066	987.257	2.067
149.932	0.001	359.389	1.772	569.002	2.027	778.454	2.066	988.028	2.066
150.573	0.003	360.185	1.774	569.642	2.027	779.222	2.066	988.672	2.067
151.354	0.001	360.822	1.775	570.417	2.028	779.874	2.066	989.450	2.067
151.985	0.001	361.603	1.779	571.064	2.028	780.653	2.066	990.091	2.067

152.766	0.002	362.238	1.779	571.846	2.028	781.283	2.066	990.869	2.066
153.408	0.002	363.026	1.782	572.487	2.029	782.071	2.066	991.507	2.067
154.200	0.002	363.661	1.783	573.257	2.029	782.709	2.066	992.290	2.067
154.835	0.003	364.432	1.786	573.903	2.029	783.488	2.066	992.932	2.066
155.621	0.002	365.078	1.787	574.679	2.029	784.129	2.066	993.712	2.067
156.247	0.001	365.860	1.790	575.325	2.029	784.907	2.067	994.349	2.067
157.034	0.002	366.505	1.791	576.097	2.030	785.545	2.066	995.132	2.066
157.674	0.002	367.286	1.795	576.734	2.031	786.335	2.066	995.771	2.067
158.456	0.002	367.917	1.796	577.515	2.031	786.962	2.066	996.551	2.067
159.102	0.002	368.696	1.800	578.161	2.031	787.757	2.066	997.194	2.066
159.883	0.002	369.338	1.800	578.943	2.032	788.394	2.066	997.972	2.066
160.514	0.003	370.118	1.803	579.583	2.032	789.177	2.066	998.617	2.066
161.301	0.002	370.754	1.804	580.365	2.032	789.814	2.066	999.395	2.066
161.936	0.002	371.543	1.806	580.996	2.031	790.593	2.066	1000.041	2.066
162.713	0.002	372.180	1.808	581.777	2.032	791.226	2.066	1000.820	2.067
163.359	0.002	372.957	1.811	582.423	2.032	792.009	2.067	1001.461	2.066
164.145	0.002	373.606	1.812	583.199	2.032	792.648	2.066	1002.245	2.066
164.770	0.002	374.380	1.814	583.845	2.032	793.436	2.066	1002.876	2.066
165.562	0.002	375.023	1.815	584.627	2.033	794.071	2.067	1003.655	2.067
166.203	0.002	375.809	1.817	585.268	2.033	794.850	2.066	1004.298	2.066
166.980	0.002	376.435	1.818	586.045	2.033	795.494	2.066	1005.079	2.066
167.619	0.002	377.216	1.821	586.690	2.033	796.276	2.067	1005.724	2.066
168.397	0.002	377.863	1.822	587.471	2.034	796.913	2.066	1006.493	2.066
169.038	0.001	378.649	1.825	588.102	2.034	797.693	2.067	1007.140	2.066
169.817	0.002	379.290	1.826	588.894	2.034	798.330	2.066	1007.925	2.066
170.455	0.002	380.062	1.828	589.518	2.035	799.108	2.067	1008.552	2.066
171.239	0.002	380.702	1.829	590.300	2.035	799.750	2.066	1009.335	2.067
171.875	0.002	381.482	1.831	590.949	2.035	800.533	2.067	1009.976	2.066
172.654	0.003	382.129	1.832	591.729	2.036	801.170	2.067	1010.756	2.066
173.296	0.002	382.910	1.835	592.370	2.036	801.963	2.066	1011.405	2.066
174.089	0.002	383.551	1.836	593.152	2.036	802.601	2.066	1012.184	2.066
174.726	0.001	384.332	1.839	593.782	2.036	803.379	2.067	1012.826	2.066
175.505	0.003	384.963	1.840	594.574	2.036	804.021	2.066	1013.604	2.067
176.147	0.002	385.753	1.842	595.200	2.036	804.799	2.066	1014.247	2.066
176.925	0.002	386.379	1.843	595.987	2.037	805.441	2.067	1015.024	2.066
177.563	0.002	387.171	1.845	596.621	2.038	806.221	2.067	1015.664	2.066

178.346	0.002	387.806	1.846	597.403	2.038	806.857	2.067	1016.438	2.066
178.983	0.001	388.582	1.847	598.048	2.038	807.631	2.067	1017.090	2.065
179.762	0.002	389.223	1.848	598.829	2.038	808.283	2.067	1017.859	2.066
180.405	0.002	390.010	1.850	599.471	2.038	809.061	2.068	1018.502	2.066
181.190	0.002	390.641	1.852	600.243	2.038	809.704	2.067	1019.285	2.066
181.826	0.002	391.424	1.853	600.895	2.038	810.483	2.067	1019.923	2.066
182.610	0.002	392.070	1.855	601.674	2.038	811.114	2.066	1020.702	2.065
183.237	0.003	392.850	1.856	602.312	2.039	811.891	2.067	1021.344	2.066
184.030	0.003	393.486	1.857	603.094	2.040	812.535	2.067	1022.128	2.067
184.668	0.002	394.267	1.858	603.732	2.039	813.314	2.067	1022.765	2.066
185.450	0.003	394.908	1.860	604.511	2.040	813.951	2.067	1023.549	2.066
186.086	0.003	395.690	1.862	605.153	2.040	814.734	2.067	1024.187	2.066
186.866	0.002	396.326	1.863	605.930	2.040	815.371	2.067	1024.963	2.066
187.510	0.002	397.102	1.864	606.568	2.041	816.155	2.068	1025.606	2.065
188.287	0.002	397.753	1.865	607.345	2.040	816.796	2.067	1026.393	2.066
188.928	0.002	398.531	1.866	607.987	2.041	817.574	2.067	1027.030	2.066
189.711	0.002	399.174	1.867	608.766	2.041	818.212	2.067	1027.813	2.066
190.345	0.002	399.946	1.869	609.404	2.041	818.995	2.067	1028.440	2.065
191.124	0.002	400.591	1.870	610.185	2.041	819.638	2.067	1029.220	2.065
191.765	0.002	401.368	1.872	610.838	2.041	820.423	2.068	1029.873	2.066
192.548	0.003	402.010	1.873	611.606	2.042	821.065	2.067	1030.640	2.066
193.188	0.003	402.788	1.874	612.248	2.042	821.839	2.068	1031.294	2.065
193.972	0.003	403.426	1.876	613.031	2.042	822.477	2.067	1032.071	2.065
194.604	0.002	404.210	1.878	613.675	2.042	823.255	2.067	1032.714	2.065
195.388	0.002	404.846	1.879	614.460	2.042	823.896	2.067	1033.486	2.066
196.024	0.003	405.630	1.880	615.094	2.043	824.690	2.068	1034.124	2.065
196.811	0.003	406.267	1.881	615.881	2.043	825.319	2.068	1034.908	2.065
197.454	0.002	407.059	1.883	616.521	2.043	826.096	2.067	1035.542	2.065
198.223	0.002	407.698	1.883	617.302	2.043	826.739	2.068	1036.329	2.065
198.861	0.002	408.476	1.884	617.929	2.043	827.518	2.067	1036.976	2.066
199.649	0.003	409.118	1.885	618.721	2.044	828.155	2.068	1037.750	2.065
200.287	0.003	409.897	1.887	619.351	2.044	828.937	2.068	1038.393	2.066
201.062	0.002	410.535	1.887	620.132	2.044	829.591	2.067	1039.170	2.065
201.705	0.003	411.319	1.890	620.773	2.044	830.370	2.067	1039.812	2.065
202.484	0.003	411.956	1.890	621.550	2.045	830.997	2.068	1040.590	2.065
203.136	0.003	412.735	1.892	622.196	2.044	831.791	2.068	1041.236	2.065

203.914	0.002	413.378	1.892	622.983	2.045	832.429	2.067	1042.017	2.066
204.561	0.002	414.156	1.893	623.624	2.045	833.207	2.068	1042.650	2.066
205.326	0.002	414.793	1.893	624.391	2.046	833.848	2.068	1043.429	2.066
205.963	0.003	415.572	1.896	625.042	2.045	834.627	2.067	1044.065	2.066
206.747	0.002	416.222	1.897	625.819	2.045	835.271	2.068	1044.855	2.065
207.388	0.003	417.000	1.899	626.465	2.046	836.045	2.067	1045.496	2.066
208.168	0.003	417.639	1.899	627.237	2.046	836.683	2.068	1046.268	2.064
208.810	0.003	418.421	1.900	627.875	2.046	837.473	2.067	1046.909	2.064
209.593	0.002	419.058	1.901	628.652	2.046	838.114	2.068	NaN	NaN

表 9: 黄冰糖燃烧热的测定

t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K	t/s	ΔT/K
0.636	0.000	221.549	0.232	442.322	1.045	663.248	1.156	884.037	1.191
1.418	0.000	222.185	0.244	443.116	1.047	663.885	1.156	884.815	1.189
2.053	0.000	222.976	0.257	443.743	1.047	664.673	1.156	885.456	1.191
2.836	0.000	223.612	0.266	444.529	1.049	665.310	1.156	886.235	1.189
3.477	0.001	224.401	0.276	445.167	1.049	666.089	1.156	886.873	1.191
4.255	0.000	225.037	0.281	445.950	1.049	666.731	1.156	887.656	1.189
4.896	0.000	225.813	0.289	446.592	1.049	667.514	1.156	888.293	1.192
5.676	0.000	226.445	0.294	447.371	1.050	668.152	1.157	889.072	1.191
6.313	0.001	227.231	0.311	448.009	1.050	668.930	1.156	889.715	1.191
7.089	0.000	227.873	0.316	448.793	1.052	669.562	1.156	890.492	1.191
7.736	0.000	228.651	0.326	449.435	1.052	670.346	1.156	891.131	1.189
8.508	0.000	229.288	0.331	450.215	1.054	670.985	1.159	891.909	1.189
9.154	-0.001	230.082	0.339	450.850	1.055	671.772	1.157	892.550	1.191
9.936	0.000	230.709	0.346	451.638	1.054	672.413	1.157	893.329	1.191
10.571	0.000	231.503	0.357	452.276	1.055	673.184	1.157	893.969	1.191
11.348	0.000	232.141	0.366	453.044	1.055	673.827	1.159	894.746	1.191
12.001	-0.001	232.914	0.377	453.686	1.055	674.607	1.157	895.389	1.191
12.768	0.000	233.556	0.382	454.467	1.057	675.245	1.159	896.168	1.191
13.410	0.000	234.339	0.392	455.105	1.057	676.031	1.157	896.810	1.191
14.198	0.000	234.982	0.399	455.888	1.057	676.671	1.159	897.587	1.189
14.831	0.000	235.753	0.416	456.524	1.059	677.452	1.159	898.240	1.191
15.614	0.000	236.391	0.426	457.319	1.059	678.088	1.159	899.018	1.191
16.259	-0.001	237.177	0.448	457.956	1.059	678.874	1.161	899.653	1.192

17.038	0.000	237.819	0.456	458.740	1.060	679.514	1.161	900.430	1.192
17.680	0.000	238.597	0.468	459.376	1.060	680.290	1.159	901.069	1.191
18.462	0.000	239.230	0.473	460.155	1.062	680.934	1.159	901.851	1.191
19.101	0.000	240.015	0.479	460.796	1.060	681.710	1.159	902.488	1.191
19.884	-0.001	240.652	0.483	461.573	1.062	682.351	1.159	903.273	1.192
20.521	-0.001	241.429	0.491	462.212	1.064	683.127	1.159	903.915	1.191
21.301	-0.001	242.078	0.499	462.996	1.062	683.766	1.161	904.701	1.191
21.943	0.000	242.857	0.511	463.632	1.064	684.550	1.161	905.338	1.191
22.711	0.000	243.496	0.518	464.416	1.065	685.184	1.161	906.116	1.192
23.363	0.000	244.276	0.531	465.054	1.065	685.975	1.159	906.760	1.192
24.135	-0.001	244.921	0.536	465.837	1.065	686.605	1.159	907.540	1.191
24.777	-0.001	245.698	0.551	466.473	1.065	687.392	1.161	908.171	1.191
25.554	-0.001	246.335	0.561	467.253	1.067	688.034	1.161	908.957	1.192
26.193	-0.001	247.121	0.578	467.892	1.067	688.802	1.161	909.588	1.191
26.976	0.000	247.762	0.585	468.678	1.069	689.448	1.161	910.380	1.191
27.613	0.000	248.533	0.591	469.313	1.067	690.229	1.161	911.020	1.192
28.392	-0.001	249.175	0.595	470.098	1.069	690.874	1.162	911.802	1.192
29.032	-0.001	249.957	0.598	470.739	1.069	691.656	1.161	912.433	1.191
29.826	0.000	250.603	0.601	471.510	1.070	692.297	1.162	913.214	1.191
30.463	-0.001	251.378	0.606	472.161	1.070	693.062	1.161	913.855	1.192
31.246	-0.001	252.020	0.606	472.932	1.070	693.719	1.162	914.640	1.192
31.872	-0.001	252.801	0.611	473.578	1.070	694.509	1.162	915.273	1.194
32.664	-0.001	253.438	0.616	474.363	1.072	695.133	1.164	916.058	1.191
33.294	0.000	254.224	0.625	475.003	1.072	695.915	1.162	916.700	1.192
34.075	-0.001	254.865	0.628	475.768	1.072	696.562	1.162	917.477	1.192
34.717	-0.001	255.647	0.636	476.415	1.074	697.337	1.162	918.117	1.192
35.504	-0.001	256.275	0.638	477.196	1.074	697.977	1.162	918.902	1.194
36.144	-0.001	257.053	0.645	477.837	1.074	698.759	1.162	919.539	1.194
36.927	-0.001	257.691	0.648	478.618	1.075	699.401	1.164	920.323	1.192
37.564	0.000	258.483	0.656	479.259	1.074	700.182	1.164	920.960	1.192
38.334	-0.001	259.122	0.658	480.030	1.075	700.823	1.166	921.743	1.192
38.985	-0.001	259.905	0.665	480.676	1.077	701.610	1.164	922.369	1.192
39.766	-0.001	260.542	0.668	481.462	1.077	702.250	1.164	923.163	1.192
40.402	-0.001	261.315	0.678	482.103	1.077	703.027	1.164	923.801	1.192
41.186	-0.001	261.953	0.683	482.869	1.077	703.668	1.164	924.571	1.192
41.826	-0.002	262.736	0.690	483.523	1.077	704.437	1.164	925.214	1.194

42.603	-0.001	263.378	0.693	484.294	1.079	705.084	1.166	925.993	1.194
43.243	-0.001	264.154	0.698	484.935	1.080	705.864	1.164	926.630	1.192
44.025	0.000	264.792	0.700	485.712	1.080	706.504	1.166	927.412	1.194
44.657	-0.001	265.580	0.705	486.363	1.079	707.288	1.166	928.049	1.194
45.443	-0.001	266.217	0.706	487.140	1.080	707.926	1.166	928.843	1.192
46.086	-0.001	266.996	0.710	487.781	1.082	708.709	1.166	929.483	1.192
46.863	-0.001	267.633	0.711	488.552	1.080	709.344	1.166	930.261	1.192
47.504	-0.001	268.421	0.715	489.192	1.080	710.123	1.166	930.899	1.192
48.280	-0.002	269.058	0.718	489.984	1.082	710.761	1.167	931.670	1.192
48.927	-0.001	269.837	0.721	490.615	1.082	711.543	1.166	932.313	1.192
49.708	-0.001	270.479	0.725	491.401	1.084	712.181	1.166	933.095	1.194
50.343	-0.001	271.257	0.728	492.042	1.084	712.959	1.167	933.825	1.192
51.120	-0.001	271.895	0.728	492.824	1.084	713.601	1.167	934.519	1.194
51.766	-0.001	272.681	0.731	493.459	1.084	714.379	1.169	935.157	1.194
52.543	-0.001	273.317	0.735	494.241	1.086	715.017	1.167	935.943	1.194
53.179	0.000	274.109	0.741	494.882	1.086	715.810	1.167	936.584	1.194
53.960	-0.001	274.750	0.741	495.662	1.086	716.436	1.167	937.363	1.194
54.597	0.000	275.518	0.745	496.293	1.086	717.231	1.167	938.001	1.192
55.389	0.000	276.161	0.746	497.085	1.087	717.869	1.167	938.779	1.192
56.025	-0.001	276.940	0.750	497.715	1.086	718.641	1.169	939.420	1.192
56.811	-0.001	277.581	0.752	498.493	1.087	719.278	1.167	940.198	1.194
57.442	-0.001	278.360	0.755	499.135	1.089	720.073	1.167	940.835	1.194
58.219	-0.001	278.999	0.755	499.917	1.087	720.705	1.167	941.618	1.194
58.869	-0.001	279.781	0.762	500.552	1.089	721.488	1.171	942.256	1.194
59.639	-0.001	280.418	0.765	501.333	1.089	722.127	1.169	943.041	1.196
60.291	-0.001	281.198	0.772	501.984	1.087	722.905	1.169	943.680	1.194
61.068	-0.001	281.839	0.775	502.755	1.091	723.551	1.167	944.466	1.192
61.698	0.000	282.622	0.780	503.402	1.091	724.328	1.169	945.105	1.194
62.485	-0.001	283.260	0.782	504.182	1.091	724.966	1.169	945.889	1.194
63.121	-0.001	284.048	0.782	504.812	1.091	725.749	1.169	946.513	1.194
63.906	-0.001	284.690	0.785	505.605	1.092	726.385	1.169	947.300	1.194
64.543	-0.001	285.468	0.787	506.240	1.092	727.165	1.169	947.944	1.194
65.319	-0.001	286.107	0.788	507.016	1.092	727.807	1.169	948.717	1.194
65.965	-0.001	286.890	0.792	507.662	1.094	728.584	1.169	949.353	1.194
66.746	0.000	287.526	0.793	508.433	1.094	729.222	1.171	950.149	1.194
67.377	-0.001	288.312	0.795	509.087	1.092	730.001	1.171	950.775	1.194

68.169	-0.001	288.950	0.797	509.860	1.094	730.642	1.169	951.569	1.194
68.799	0.000	289.726	0.800	510.496	1.096	731.421	1.171	952.207	1.194
69.586	-0.001	290.357	0.802	511.288	1.094	732.059	1.169	952.982	1.194
70.227	-0.001	291.151	0.803	511.914	1.096	732.847	1.171	953.628	1.194
71.008	-0.001	291.777	0.803	512.703	1.097	733.483	1.169	954.407	1.194
71.639	-0.001	292.571	0.807	513.340	1.096	734.262	1.171	955.043	1.196
72.426	-0.001	293.209	0.810	514.118	1.096	734.905	1.171	955.826	1.196
73.067	-0.001	293.978	0.813	514.760	1.097	735.689	1.171	956.468	1.194
73.848	-0.001	294.620	0.813	515.538	1.099	736.326	1.171	957.248	1.194
74.482	-0.001	295.398	0.817	516.176	1.099	737.109	1.171	957.879	1.196
75.261	-0.001	296.042	0.818	516.960	1.099	737.752	1.172	958.659	1.194
75.909	-0.001	296.820	0.820	517.602	1.099	738.530	1.171	959.296	1.194
76.694	-0.001	297.473	0.825	518.381	1.101	739.168	1.171	960.075	1.196
77.325	-0.001	298.240	0.828	519.015	1.101	739.945	1.171	960.722	1.196
78.108	-0.001	298.888	0.828	519.804	1.099	740.587	1.172	961.500	1.196
78.753	-0.001	299.667	0.830	520.441	1.101	741.375	1.171	962.143	1.196
79.535	-0.001	300.304	0.832	521.220	1.101	742.012	1.172	962.926	1.194
80.162	0.000	301.088	0.835	521.867	1.101	742.794	1.172	963.569	1.196
80.940	-0.001	301.725	0.837	522.640	1.102	743.425	1.172	964.349	1.196
81.592	0.000	302.503	0.838	523.279	1.102	744.216	1.172	964.980	1.196
82.376	-0.001	303.145	0.840	524.063	1.102	744.846	1.174	965.759	1.196
83.003	-0.001	303.934	0.843	524.706	1.104	745.629	1.171	966.402	1.196
83.789	-0.001	304.562	0.843	525.484	1.104	746.270	1.174	967.185	1.194
84.427	-0.001	305.340	0.845	526.125	1.104	747.051	1.172	967.823	1.196
85.210	-0.001	305.983	0.847	526.903	1.106	747.692	1.172	968.600	1.196
85.848	0.000	306.762	0.848	527.546	1.106	748.463	1.174	969.238	1.196
86.626	-0.001	307.414	0.848	528.329	1.104	749.104	1.174	970.027	1.197
87.275	-0.001	308.186	0.852	528.962	1.104	749.883	1.174	970.665	1.196
88.054	-0.001	308.823	0.853	529.750	1.107	750.524	1.172	971.449	1.196
88.692	-0.002	309.610	0.855	530.386	1.107	751.317	1.174	972.077	1.197
89.473	-0.001	310.250	0.857	531.167	1.106	751.947	1.172	972.862	1.196
90.101	-0.001	311.027	0.860	531.802	1.107	752.738	1.174	973.498	1.196
90.895	-0.002	311.668	0.862	532.580	1.107	753.373	1.174	974.282	1.196
91.532	-0.001	312.455	0.863	533.220	1.107	754.155	1.174	974.919	1.194
92.316	-0.001	313.085	0.863	534.002	1.107	754.787	1.174	975.704	1.196
92.953	-0.001	313.867	0.867	534.640	1.107	755.564	1.174	976.341	1.196

93.734	-0.001	314.510	0.868	535.431	1.109	756.204	1.174	977.130	1.196
94.372	-0.001	315.289	0.870	536.066	1.107	756.996	1.174	977.768	1.196
95.144	-0.001	315.934	0.870	536.849	1.109	757.627	1.174	978.552	1.196
95.785	0.000	316.711	0.872	537.485	1.109	758.413	1.176	979.179	1.196
96.573	-0.002	317.356	0.875	538.260	1.111	759.049	1.176	979.964	1.196
97.213	-0.002	318.135	0.875	538.901	1.109	759.836	1.176	980.606	1.196
97.989	-0.001	318.761	0.875	539.681	1.111	760.471	1.176	981.387	1.196
98.626	-0.001	319.548	0.878	540.327	1.111	761.252	1.176	982.022	1.196
99.417	-0.001	320.188	0.880	541.103	1.111	761.893	1.176	982.809	1.197
100.056	-0.001	320.971	0.882	541.745	1.112	762.669	1.174	983.445	1.196
100.825	-0.001	321.611	0.883	542.521	1.112	763.305	1.176	984.221	1.196
101.467	-0.001	322.397	0.885	543.171	1.112	764.102	1.176	984.860	1.196
102.245	0.000	323.033	0.885	543.953	1.112	764.729	1.177	985.647	1.197
102.889	-0.001	323.815	0.887	544.588	1.114	765.510	1.176	986.278	1.197
103.678	-0.001	324.450	0.888	545.370	1.114	766.145	1.177	987.061	1.196
104.309	-0.001	325.226	0.892	546.009	1.114	766.927	1.176	987.702	1.196
105.088	-0.001	325.867	0.892	546.791	1.114	767.578	1.176	988.495	1.197
105.731	-0.002	326.653	0.895	547.427	1.114	768.359	1.176	989.119	1.197
106.506	-0.001	327.294	0.893	548.203	1.114	768.995	1.177	989.902	1.196
107.149	-0.001	328.070	0.898	548.844	1.116	769.772	1.177	990.548	1.196
107.930	-0.002	328.716	0.898	549.633	1.116	770.407	1.177	991.323	1.197
108.565	-0.001	329.487	0.900	550.264	1.117	771.188	1.177	991.960	1.196
109.359	0.000	330.136	0.900	551.040	1.116	771.829	1.177	992.751	1.197
110.000	-0.001	330.913	0.903	551.691	1.117	772.615	1.177	993.390	1.196
110.776	-0.001	331.554	0.905	552.468	1.117	773.256	1.177	994.168	1.197
111.414	-0.001	332.333	0.907	553.112	1.117	774.033	1.177	994.807	1.197
112.197	0.000	332.972	0.907	553.893	1.117	774.680	1.177	995.589	1.197
112.827	-0.001	333.754	0.908	554.528	1.117	775.452	1.177	996.227	1.196
113.614	-0.001	334.386	0.910	555.305	1.117	776.100	1.177	997.007	1.197
114.261	-0.001	335.166	0.912	555.952	1.119	776.877	1.177	997.649	1.197
115.037	-0.001	335.808	0.912	556.732	1.119	777.519	1.179	998.427	1.197
115.667	-0.001	336.586	0.915	557.368	1.119	778.287	1.177	999.066	1.199
116.455	-0.001	337.240	0.915	558.145	1.117	778.941	1.177	999.843	1.197
117.091	-0.001	338.008	0.917	558.795	1.119	779.709	1.179	1000.484	1.197
117.878	-0.001	338.650	0.917	559.564	1.119	780.347	1.179	1001.263	1.197
118.508	-0.001	339.435	0.920	560.216	1.119	781.141	1.177	1001.906	1.197

119.294	-0.001	340.073	0.920	560.982	1.119	781.768	1.177	1002.689	1.199
119.936	-0.002	340.861	0.924	561.622	1.121	782.562	1.177	1003.326	1.197
120.720	-0.001	341.498	0.924	562.409	1.122	783.190	1.179	1004.105	1.197
121.352	-0.001	342.281	0.924	563.045	1.122	783.969	1.179	1004.756	1.197
122.134	-0.001	342.908	0.925	563.831	1.122	784.618	1.179	1005.522	1.197
122.778	-0.001	343.702	0.927	564.473	1.122	785.396	1.179	1006.161	1.197
123.560	-0.001	344.339	0.927	565.252	1.122	786.035	1.179	1006.952	1.197
124.194	-0.001	345.117	0.930	565.895	1.122	786.818	1.181	1007.584	1.197
124.979	-0.001	345.760	0.929	566.673	1.122	787.455	1.179	1008.370	1.197
125.614	-0.001	346.537	0.930	567.315	1.122	788.233	1.179	1009.009	1.196
126.400	-0.001	347.176	0.932	568.089	1.122	788.873	1.179	1009.791	1.197
127.040	-0.001	347.958	0.934	568.727	1.124	789.652	1.179	1010.429	1.196
127.822	-0.001	348.599	0.934	569.505	1.124	790.290	1.179	1011.208	1.197
128.453	-0.001	349.376	0.935	570.149	1.124	791.084	1.179	1011.850	1.197
129.237	-0.001	350.017	0.937	570.926	1.124	791.711	1.179	1012.634	1.196
129.883	-0.001	350.797	0.937	571.563	1.126	792.504	1.179	1013.272	1.196
130.664	-0.001	351.428	0.939	572.347	1.126	793.143	1.179	1014.050	1.199
131.296	-0.001	352.220	0.942	572.990	1.126	793.911	1.179	1014.685	1.197
132.077	0.000	352.850	0.942	573.768	1.126	794.560	1.181	1015.478	1.199
132.718	-0.001	353.632	0.944	574.418	1.127	795.345	1.181	1016.117	1.199
133.505	-0.001	354.279	0.944	575.186	1.126	795.972	1.181	1016.888	1.197
134.133	-0.001	355.059	0.945	575.823	1.126	796.765	1.181	1017.535	1.197
134.915	0.000	355.701	0.947	576.607	1.127	797.403	1.181	1018.304	1.197
135.561	-0.001	356.473	0.947	577.248	1.127	798.181	1.179	1018.946	1.199
136.344	-0.001	357.113	0.949	578.026	1.127	798.823	1.181	1019.730	1.197
136.978	-0.001	357.895	0.949	578.664	1.127	799.593	1.181	1020.368	1.197
137.752	-0.001	358.541	0.950	579.446	1.129	800.237	1.181	1021.147	1.197
138.397	-0.001	359.323	0.950	580.090	1.129	801.020	1.181	1021.789	1.197
139.179	-0.001	359.953	0.952	580.868	1.129	801.658	1.181	1022.567	1.197
139.825	0.000	360.739	0.952	581.505	1.129	802.440	1.181	1023.209	1.196
140.596	0.000	361.370	0.954	582.289	1.129	803.073	1.182	1023.993	1.197
141.242	-0.001	362.151	0.955	582.927	1.129	803.866	1.181	1024.623	1.199
142.018	-0.001	362.793	0.955	583.710	1.131	804.500	1.181	1025.417	1.197
142.664	0.000	363.580	0.957	584.357	1.131	805.285	1.181	1026.050	1.197
143.441	-0.001	364.210	0.959	585.136	1.131	805.922	1.182	1026.828	1.199
144.074	-0.001	365.002	0.959	585.774	1.132	806.705	1.181	1027.471	1.199

144.856	-0.001	365.633	0.960	586.549	1.132	807.340	1.181	1028.250	1.199
145.506	-0.001	366.425	0.962	587.196	1.132	808.121	1.181	1028.892	1.197
146.272	0.000	367.056	0.962	587.974	1.134	808.757	1.181	1029.675	1.199
146.913	0.000	367.834	0.964	588.609	1.132	809.535	1.182	1030.312	1.197
147.705	-0.001	368.471	0.964	589.395	1.132	810.186	1.182	1031.097	1.199
148.341	0.000	369.261	0.965	590.034	1.132	810.952	1.182	1031.730	1.199
149.117	0.000	369.898	0.965	590.819	1.134	811.600	1.182	1032.513	1.199
149.764	0.000	370.683	0.969	591.456	1.134	812.382	1.184	1033.156	1.199
150.534	-0.001	371.324	0.970	592.233	1.134	813.017	1.182	1033.935	1.199
151.182	-0.001	372.103	0.970	592.879	1.134	813.798	1.182	1034.565	1.197
151.961	-0.001	372.741	0.970	593.658	1.134	814.444	1.182	1035.359	1.199
152.603	0.000	373.524	0.970	594.296	1.134	815.225	1.182	1035.986	1.199
153.381	-0.001	374.152	0.972	595.073	1.134	815.867	1.182	1036.781	1.201
154.017	-0.001	374.946	0.974	595.714	1.134	816.637	1.182	1037.407	1.199
154.795	-0.001	375.582	0.974	596.490	1.134	817.283	1.184	1038.191	1.197
155.437	-0.001	376.355	0.975	597.126	1.134	818.065	1.182	1038.829	1.199
156.221	-0.001	376.998	0.974	597.908	1.136	818.707	1.182	1039.612	1.197
156.860	-0.001	377.776	0.977	598.559	1.134	819.483	1.182	1040.254	1.199
157.644	-0.001	378.424	0.977	599.336	1.137	820.118	1.182	1041.033	1.199
158.280	-0.002	379.201	0.979	599.977	1.136	820.900	1.182	1041.671	1.199
159.065	0.000	379.838	0.980	600.757	1.136	821.542	1.184	1042.453	1.199
159.707	-0.001	380.619	0.982	601.393	1.136	822.319	1.182	1043.093	1.199
160.484	-0.001	381.257	0.982	602.170	1.136	822.957	1.184	1043.873	1.197
161.122	-0.001	382.037	0.982	602.813	1.137	823.749	1.184	1044.513	1.199
161.904	-0.001	382.673	0.982	603.595	1.137	824.374	1.184	1045.297	1.199
162.546	0.000	383.465	0.984	604.229	1.137	825.157	1.184	1045.939	1.199
163.325	0.000	384.092	0.985	605.009	1.137	825.798	1.184	1046.718	1.197
163.963	-0.001	384.878	0.985	605.651	1.137	826.580	1.184	1047.359	1.199
164.747	0.000	385.525	0.987	606.433	1.137	827.221	1.186	1048.143	1.199
165.383	0.000	386.309	0.987	607.071	1.139	827.997	1.184	1048.771	1.201
166.156	-0.001	386.936	0.989	607.849	1.139	828.648	1.182	1049.563	1.199
166.799	0.000	387.720	0.990	608.490	1.139	829.429	1.184	1050.201	1.199
167.575	0.000	388.364	0.990	609.276	1.139	830.054	1.184	1050.971	1.199
168.229	-0.001	389.140	0.992	609.914	1.139	830.836	1.186	1051.622	1.201
168.997	0.000	389.782	0.992	610.697	1.141	831.477	1.186	1052.404	1.199
169.639	-0.001	390.560	0.994	611.334	1.141	832.269	1.186	1053.028	1.199

170.417	-0.001	391.203	0.994	612.119	1.141	832.910	1.186	1053.812	1.199
171.056	-0.001	391.982	0.994	612.761	1.141	833.691	1.184	1054.454	1.197
171.840	0.000	392.623	0.995	613.539	1.139	834.321	1.186	1055.233	1.201
172.476	-0.001	393.402	0.997	614.183	1.141	835.103	1.186	1055.875	1.201
173.271	-0.001	394.047	0.999	614.962	1.141	835.750	1.184	1056.659	1.201
173.911	-0.001	394.829	0.999	615.593	1.141	836.526	1.184	1057.295	1.201
174.679	0.000	395.466	1.000	616.373	1.142	837.160	1.186	1058.075	1.201
175.320	0.000	396.250	0.999	617.012	1.142	837.951	1.184	1058.722	1.201
176.098	-0.001	396.876	1.000	617.795	1.141	838.586	1.186	1059.499	1.201
176.740	-0.001	397.655	1.002	618.432	1.141	839.368	1.186	1060.137	1.199
177.518	0.000	398.307	1.000	619.215	1.142	840.003	1.187	1060.915	1.199
178.157	-0.001	399.086	1.004	619.857	1.142	840.779	1.184	1061.562	1.199
178.940	-0.001	399.728	1.004	620.634	1.144	841.416	1.186	1062.341	1.201
179.582	-0.001	400.506	1.005	621.272	1.142	842.208	1.186	1062.969	1.201
180.362	0.000	401.150	1.007	622.051	1.142	842.838	1.186	1063.762	1.201
181.005	0.000	401.917	1.007	622.693	1.142	843.620	1.186	1064.405	1.201
181.789	-0.001	402.570	1.007	623.486	1.144	844.261	1.186	1065.174	1.199
182.426	-0.001	403.339	1.007	624.125	1.144	845.042	1.186	1065.816	1.201
183.205	-0.001	403.982	1.009	624.904	1.144	845.690	1.186	1066.593	1.199
183.838	0.000	404.765	1.009	625.541	1.142	846.467	1.186	1067.244	1.201
184.630	-0.001	405.402	1.010	626.319	1.144	847.108	1.186	1068.021	1.199
185.268	-0.001	406.187	1.012	626.962	1.146	847.880	1.186	1068.665	1.199
186.052	-0.001	406.830	1.012	627.741	1.146	848.526	1.186	1069.437	1.199
186.679	0.000	407.604	1.012	628.377	1.146	849.302	1.186	1070.084	1.199
187.473	0.000	408.242	1.014	629.167	1.146	849.946	1.187	1070.860	1.201
188.104	0.000	409.026	1.014	629.796	1.146	850.723	1.186	1071.504	1.199
188.884	-0.001	409.664	1.015	630.575	1.146	851.359	1.186	1072.282	1.199
189.521	0.000	410.442	1.015	631.213	1.146	852.141	1.187	1072.921	1.199
190.300	0.000	411.091	1.017	631.997	1.147	852.787	1.187	1073.705	1.199
190.942	0.001	411.870	1.017	632.634	1.146	853.560	1.187	1074.345	1.201
191.729	0.001	412.507	1.017	633.428	1.146	854.200	1.186	1075.127	1.201
192.367	0.002	413.286	1.020	634.055	1.146	854.991	1.187	1075.757	1.201
193.156	0.003	413.928	1.019	634.838	1.147	855.628	1.187	1076.535	1.201
193.795	0.007	414.703	1.020	635.475	1.147	856.412	1.187	1077.172	1.199
194.576	0.008	415.340	1.020	636.260	1.147	857.042	1.187	1077.958	1.199
195.203	0.008	416.129	1.022	636.902	1.149	857.823	1.187	1078.604	1.201

195.992	0.012	416.767	1.022	637.686	1.147	858.469	1.187	1079.385	1.201
196.626	0.013	417.545	1.022	638.323	1.147	859.250	1.187	1080.020	1.199
197.410	0.015	418.188	1.024	639.107	1.147	859.880	1.189	1080.803	1.201
198.053	0.017	418.967	1.024	639.745	1.149	860.671	1.187	1081.433	1.201
198.831	0.020	419.609	1.025	640.523	1.149	861.312	1.187	1082.225	1.199
199.468	0.023	420.387	1.025	641.164	1.149	862.088	1.187	1082.861	1.201
200.252	0.028	421.022	1.027	641.936	1.147	862.729	1.187	1083.634	1.201
200.890	0.030	421.801	1.027	642.583	1.149	863.501	1.187	1084.275	1.201
201.670	0.037	422.438	1.027	643.359	1.149	864.141	1.187	1085.056	1.199
202.311	0.040	423.222	1.029	643.999	1.149	864.922	1.189	1085.698	1.201
203.091	0.045	423.860	1.029	644.783	1.149	865.568	1.189	1086.475	1.201
203.729	0.052	424.655	1.030	645.414	1.152	866.355	1.187	1087.115	1.202
204.505	0.060	425.281	1.032	646.204	1.151	866.994	1.189	1087.896	1.201
205.148	0.065	426.067	1.030	646.849	1.149	867.761	1.187	1088.543	1.199
205.927	0.070	426.706	1.034	647.628	1.149	868.403	1.187	1089.325	1.201
206.569	0.073	427.484	1.034	648.267	1.151	869.183	1.187	1089.956	1.201
207.352	0.080	428.127	1.032	649.045	1.152	869.830	1.187	1090.748	1.201
207.990	0.084	428.906	1.032	649.689	1.152	870.613	1.187	1091.378	1.201
208.769	0.090	429.544	1.034	650.466	1.152	871.249	1.189	1092.159	1.201
209.404	0.095	430.329	1.035	651.109	1.151	872.029	1.187	1092.800	1.201
210.199	0.102	430.975	1.035	651.878	1.152	872.669	1.189	1093.586	1.201
210.837	0.107	431.751	1.035	652.530	1.152	873.452	1.189	1094.227	1.201
211.603	0.117	432.387	1.037	653.298	1.152	874.090	1.189	1094.998	1.201
212.246	0.120	433.163	1.037	653.936	1.152	874.869	1.189	1095.645	1.201
213.025	0.129	433.810	1.037	654.718	1.152	875.510	1.189	1096.429	1.201
213.678	0.135	434.593	1.037	655.360	1.152	876.289	1.189	1097.065	1.201
214.445	0.142	435.231	1.037	656.139	1.154	876.927	1.189	1097.847	1.201
215.097	0.149	436.007	1.040	656.784	1.152	877.711	1.189	1098.482	1.201
215.865	0.160	436.644	1.040	657.567	1.154	878.347	1.189	1099.259	1.201
216.516	0.165	437.435	1.042	658.204	1.154	879.125	1.191	1099.908	1.199
217.298	0.180	438.074	1.042	658.984	1.156	879.763	1.191	1100.687	1.201
217.925	0.187	438.854	1.042	659.624	1.154	880.545	1.191	1101.328	1.201
218.716	0.199	439.495	1.044	660.408	1.152	881.184	1.191	1102.100	1.201
219.351	0.204	440.278	1.045	661.046	1.154	881.979	1.189	1102.742	1.201
220.128	0.212	440.917	1.044	661.826	1.154	882.604	1.189	1103.528	1.201
220.774	0.217	441.696	1.045	662.468	1.154	883.398	1.191	1104.167	1.201

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