CHAPTER 1: SUPPLEMENTARY SOLUTIONS
MEASUREMENTS

S1-1. (a) 2×10^{12} J (c) 3.7×10^{7} m (e) 8.42×10^{-10} F
(b) 3.7×10^{-2} m (d) 4×10^{-1} K (f) 1.84×10^{4} Pa

S1-2. (a) 80 μmol (b) 10 GW (c) 400 nL (d) 3 cm (e) 180 THz (f) 5.37 TΩ

S1-3. $\dfrac{800 \times 10^{-12}\ \cancel{K}}{43 \times 10^{-6}\ \cancel{K}} = 1.9 \times 10^{-5}$

S1-4. 1 atm = 101 325 N/m^2 and 1 torr = 133.322 N/m^2
760×1 torr = $760 \times 133.322\ N/m^2$ = 101 325 N/m^2 = 1 atm

S1-5. mass of solution = (250 ~~mL~~) (1.00 g/~~mL~~) = 250 g

$$\text{ppm} = \frac{13.7 \times 10^{-6}\ \cancel{g}}{250\ \cancel{g}} \times 10^{6} = 0.054\,8\ \text{ppm} \qquad \text{ppb} = \frac{13.7 \times 10^{-6}\ \cancel{g}}{250\ \cancel{g}} \times 10^{9} = 54.8\ \text{ppb}$$

S1-6. $[Na^+] = \dfrac{(154 \times 10^{-9}\ \cancel{g}/L)}{22.990\ \cancel{g}/mol}) = 6.70 \times 10^{-9}\ M = 6.70\ nM$

$[Cl^-] = \dfrac{\left(172 \times 10^{-9}\ \cancel{g}/L\right)}{35.453\ \cancel{g}/mol} = 4.85 \times 10^{-9}\ M = 4.85\ nM$

S1-7. $\text{Molarity} = \dfrac{5.00\ \cancel{(g)}\ /\ (79.101\ \cancel{(g)}/mol)}{0.457\ L} = 0.138\ M$

S1-8. (a) $\text{Mass of solution} = 0.804\ \dfrac{g}{\cancel{mL}} \times \dfrac{100\cancel{0}\ \cancel{mL}}{L} = 804\ \dfrac{g}{L}$

$$\text{Mass of ethanol} = \frac{0.950\ \text{g of ethanol}}{\cancel{\text{g of solution}}} \times \frac{804\ \cancel{\text{g of solution}}}{L} = 764\ \frac{\text{g of ethanol}}{L}$$

(b) $\dfrac{764\ \frac{\cancel{g}}{L}}{46.07\ \frac{\cancel{g}}{mol}} = 16.6\ M$

(c) 100.0 mL of solution contains 95.0 g of ethanol and 5.0 g of water.

(95.0 g of ethanol) / (46.07 g/mol) = 2.06 mol of ethanol.

$\text{Molality} = \dfrac{2.06\ \text{mol of ethanol}}{5.0 \times 10^{-3}\ \text{kg of}\ H_2O} = 412\ m$

S1-9. (a) 10.0 g of 10.2 wt % solution contains $0.102\ \dfrac{\text{g}\ NiSO_4{\cdot}6H_2O}{\cancel{\text{g solution}}} \times 10.0\ \cancel{\text{g solution}}$

$= 1.02 \text{ g NiSO}_4{\cdot}6H_2O = 3.88 \times 10^{-3} \text{ mol NiSO}_4 \cdot 6H_2O$

$$\Rightarrow (3.88 \times 10^{-3} \cancel{\text{mol Ni}}) \times \left(58.693\,4 \frac{\text{g Ni}}{\cancel{\text{mol Ni}}}\right) = 0.228 \text{ g Ni}$$

(b) There are 0.412 mol of $NiSO_4 \cdot 6H_2O$ = 108.3 g of $NiSO_4 \cdot 6H_2O$ per L of solution. From the 10.2 wt %, we can say

$$\frac{108.3 \cancel{\text{g NiSO}_4{\cdot}6\text{H}_2\text{O}}/\text{L solution}}{0.102 \cancel{\text{g NiSO}_4{\cdot}6\text{H}_2\text{O}}/\text{g solution}} = 1.06 \times 10^3 \frac{\text{g solution}}{\text{L solution}} \Rightarrow \text{density} = 1.06 \frac{\text{g}}{\text{mL}}$$

S1-10. $M_{conc} \cdot V_{conc} = M_{dil} \cdot V_{dil}$ $\quad 12.1 \frac{\text{mol}}{\cancel{\text{L}}} \times V = 1.00 \frac{\text{mol}}{\cancel{\text{L}}} \times 0.100 \text{ L} \Rightarrow V = 8.26 \text{ mL}$

Dilute 8.26 mL of 12.1 M HCl to 100.0 mL in a volumetric flask.

S1-11. We will use 100 g = 0.100 kg H_2O. Weigh out 0.100 $\cancel{\text{kg}}$ × 0.082 mol/$\cancel{\text{kg}}$ = 0.008 2 mol = 1.00 g $NaClO_4$ and dissolve in 0.100 kg H_2O.

S1-12. (a) 40.0 wt % solution:

1 L = 1 430 g of solution. 40.0% of this is 572 g CsCl = 3.40 mol

Molar concentration = 3.40 M

20.0 wt % solution: 1 L = 1 180 g solution = 236 g CsCl ⇒ 1.40 M

(b) 40 wt % solution: 1 g of solution contains 0.400 g CsCl + 0.600 g H_2O

$$\text{molality} = \frac{\text{mol CsCl}}{\text{kg H}_2\text{O}} = \frac{(0.400 \cancel{\text{g}}) / (168.37 \cancel{\text{g}}/\text{mol})}{0.000\,600 \text{ kg}} = 3.96 \frac{\text{mol}}{\text{kg}}$$

$$\text{20.0 wt \% solution:} \quad \text{molality} = \frac{(0.200 \cancel{\text{g}}) / (168.37 \cancel{\text{g}}/\text{mol})}{0.000\,800 \text{ kg}} = 1.48 \frac{\text{mol}}{\text{kg}}$$

(c) 40.0 wt % solution has a concentration of 3.40 M

$M_{con} \cdot V_{con} = M_{dil} \cdot V_{dil}$ $\quad (3.40 \text{ M}) V = (0.100 \text{ M})(0.500 \text{ L}) \Rightarrow V = 14.7 \text{ mL}$

20.0 wt % solution has a concentration of 1.40 M ⇒ V = 35.7 mL

It requires more than twice as much of the 20% solution because the 20% solution is less dense than the 40% solution.

S1-13. 4.00 mmol Fe^{3+} requires 3(4.00 mmol) = 12.0 mmol OH^-. In the first reaction, one mol of urea produces 2 mol of OH^-. Therefore 12.0 mmol OH^- is produced by 6.00 mmol urea. The required mass of urea is $(6.00 \times 10^{-3}$ mol)(60.06 g/mol) = 0.360 g. The mass of 40.0 wt % urea is (0.360 g urea)/(0.400 g urea/g solution) = 0.901 g solution. The volume of solution is (0.901 g)/(1.111 g/mL) = 0.811 mL.

S1-14. There is no uncertainty in the constant, 2π, so we divide both h and the uncertainty by 2π:

$\hbar = h/(2\pi) = 1.054\,572\,67 (\pm 0.000\,000\,64) \times 10^{-34}$ J · s.

TOOLS OF THE TRADE

S2-1. $$m = \frac{(9.947\text{g})\left(1 - \frac{0.001\ 2\text{ g/mL}}{8.0\text{ g/mL}}\right)}{\left(1 - \frac{0.001\ 2\text{ g/mL}}{0.88\text{ g/mL}}\right)} = 9.959\text{ g}$$

S2-2. $$\frac{\text{c' at }35^\circ}{0.994\ 03\text{ g/mL}} = \frac{0.027\,64\text{ M}}{0.998\,41\text{ g/mL}} = 0.027\,52$$

S2-3. 14.974 g – 9.974 g = 5.000 g.
Table 2-7 tells us that the true volume at 26°C is
(5.000 g)(1.004 3 mL/g) = 5.022 mL.
The true volume at 20°C is (5.000 g)(1.004 2 mL/g) = 5.021 mL.

S3-1. (a) 4 (b) 4 (c) 4

S3-2. (a) 5.125 (b) 5.124 (c) 5.124 (d) 0.135 2 (e) 1.52 (f) 1.53

S3-3. (a) 12.01 (c) 14 (e) –17.66 (g) 2.79×10^{-5}
(b) 10.9 (d) 14.3 (f) 5.97×10^{-3}

S3-4. 95.978

S3-5. (a)
$$\begin{array}{l} 3.4 \pm 0.2 \\ \underline{+\,2.6 \pm 0.1} \\ 6.0 \pm e \end{array} \qquad e = \sqrt{0.2^2 + 0.1^2} = 0.224$$
$$6.0 \pm e = 6.0 \pm 0.2 \ (\pm 3._7\%)$$

(b) $$\frac{3.4 \pm 0.2}{2.6 \pm 0.1} = \frac{3.4 \pm 5.88\%}{2.6 \pm 3.85\%} = 1.308 \pm e$$
$$\%e = \sqrt{5.88^2 + 3.85^2} = 7.03\%$$
Answer: $1.30_8 \pm 0.09_2 \ (\pm 7._0\%)$

(c) $$\frac{3.4(\pm 0.2)\times 10^{-8}}{2.6(\pm 0.1)\times 10^{3}} = \frac{3.4(\pm 5.88\%)\times 10^{-8}}{2.6(\pm 3.85\%)\times 10^{3}} = 1.30_8(\pm 0.09_2)\times 10^{-11}(\pm 7._0\%)$$

(d) $3.4\ (\pm 0.2) - 2.6\ (\pm 0.1) = 0.8 \pm 0.2_{24} = 0.8 \pm 28.0\%$
$0.8\ (\pm 28.0\%) \times 3.4\ (\pm 5.88\%) = 2.72 \pm 28.6\%$ Answer: $2.7_2 \pm 0.7_8\ (\pm 29\%)$

S3-6. C: 12.010 7 ± 0.000 8 H: 1.007 94 ± 0.000 07

$$\begin{array}{lcr} +6\text{C}: 6(12.010\,7 \pm 0.000\,8) & = & 72.064\,2 \pm 0.004\,8 \\ +6\text{H}: 6(1.007\,94 \pm 0.000\,07) & = & 6.047\,64 \pm 0.000\,42 \\ \hline C_6H_6: & & 78.111\,8 \pm\ ? \end{array}$$

Uncertainty $= \sqrt{0.004\,8^2 + 0.000\,43^2} = 0.004\,8$ Answer: 78.112 ± 0.005

S3-7. (a) $$\text{Molarity} = \frac{0.222\,2\ (\pm 0.090\%)\ \text{g}}{214.0010\ (\pm 0.000\,42\%)\ \frac{\text{g}}{\text{mol}} \times 0.050\,00\ (\pm 0.10\%)\ \text{L}}$$

$$\%e = \sqrt{0.090^2 + 0.000\,42^2 + 0.10^2} = 0.135\%$$

molarity $= 0.020\,76_6 \pm 0.000\,02_8$ M

(b) The uncertainty in the analysis is ~0.1%, so 0.1% uncertainty in reagent purity is significant.

S3-8. (a) $y = x^{1/2} \Rightarrow \%e_y = \frac{1}{2}\left(\frac{0.2}{3.4} \times 100\right) = 2.94\%$ Answer: $1.84_4 \pm 0.05_4$ ($\pm 2._9\%$)

(b) $y = x^2 \Rightarrow \%e_y = 2\left(\frac{0.2}{3.4} \times 100\right) = 11.76\%$ Answer: $11._6 \pm 1._4$ ($\pm 12\%$)

(c) $y = 10^x \Rightarrow e_y = (10^{3.4})(2.302\,6)\,(0.2) = 1.16 \times 10^3$

Answer: $2._{51} \pm 1._{16} \times 10^3$ ($\pm 46\%$)

(d) $y = e^x \Rightarrow e_y = (e^{3.4})\,(0.2) = 5.99$ Answer: $30._0 \pm 6._0$ ($\pm 20\%$)

(e) $y = \log x \Rightarrow e_y = 0.434\,29\left(\frac{0.2}{3.4}\right) = 0.025\,5$ Answer: $0.53_1 \pm 0.02_6$ ($\pm 4.8\%$)

(f) $y = \ln x \Rightarrow e_y = \frac{0.2}{3.4} = 0.058\,8$ Answer: $1.22_4 \pm 0.05_9$ ($\pm 4.8\%$)

S3-9. $k = \frac{R}{N} \Rightarrow \%e_k^2 = \%e_R^2 + \%e_N^2$

$$\Rightarrow \%e_k^2 = \left(\frac{100 \times 0.000070}{8.314\ 472}\right)^2 + \left(\frac{100 \times 0.000\,003\,6}{6.022\,136\,7}\right)^2$$

$$\Rightarrow \%e_k = 0.000\,844\% \Rightarrow e_k = (0.000\,008\,44)(1.380\,658) = 0.000\,012$$

S3-10. B = 10.811 ± 0.007 H = 1.007 94 ± 0.000 07

+10B:	10(10.811 ± 0.007)	=	108.110 ± 0.07
+14H:	14(1.007 94 ± 0.000 07)	=	14.111 16 ± 0.000 98
$B_{10}H_{14}3$:			122.221 ± ?

Uncertainty $= \sqrt{0.07^2 + 0.000\,98^2} = 0.07$ Answer: 122.22 ± 0.07

S4-1. (a) Mean $= \frac{1}{7}(2.310\,17 + \cdots + 2.310\,28) = 2.310\,11$

(b) Standard deviation $= \sigma = \left(\frac{\Sigma\,(x_i - \bar{x})^2}{6}\right)^{1/2} = 0.000\,14_3$

(c) Variance $= \sigma^2 = 2.0_3 \times 10^{-8}$

S4-2. (a) $z > 0 \Rightarrow 50\%$

(b) $z = -1$ to $z = +1 \Rightarrow 68.26\%$

(c) $z = -3$ to $z = +3 \Rightarrow 99.73\%$

(d) $z < -2 \Rightarrow 2.27\%$

(e) $z = -1.4$ to $z = +0.6 \Rightarrow$ area $= 0.419\,2 + 0.225\,8 = 64.50\%$

(f) $z = -1.76$ to $z = -0.18 \Rightarrow$ area $= 0.460\,6 - 0.071\,4 = 38.92\%$

Interpolations: $\left(\frac{1.76 - 1.70}{1.80 - 1.70}\right)(0.464\,1 - 0.455\,4) + 0.455\,4 = 0.460\,6$

$\left(\frac{0.18 - 0.10}{0.20 - 0.10}\right)(0.079\,3 - 0.039\,8) + 0.039\,8 = 0.071\,4$

S4-3. $y = \frac{4768 \times 20}{94.2\sqrt{2p}}\, e^{-(x - 845.2)^2/2(94.2)^2} = 104.7$ when $x = 1\,000$.

S4-4. $\bar{x} = 2.299\,47$ g, $s = 0.001\,38$ g, $n = 7$ degrees of freedom

95% confidence: $\mu = \bar{x} \pm \frac{(2.365)(0.001\,38)}{\sqrt{8}} = 2.299\,47 \pm 0.001\,15$

99% confidence: $\mu = \bar{x} \pm \frac{(3.500)(0.001\,38)}{\sqrt{8}} = 2.299\,47 \pm 0.001\,71$

S4-5. $\bar{x}_1 = 147._8$, $\bar{x}_2 = 157._2$, $s_{pooled} = 8._{90}$,

$t = \frac{157._2 - 147._8}{8._{90}}\sqrt{\frac{5 \cdot 5}{5 + 5}} = 1.67 < 2.306$ (Student's t for 8 degrees of freedom)

The difference is <u>not</u> significant.

S4-6. $\bar{x} = 0.131_{17}$, $s = 0.002_{93}$

$t_{calculated} = \frac{|\text{known value} - \bar{x}|}{s}\sqrt{n} = \frac{|0.137 - 0.13117|}{0.00293}\sqrt{6} = 4.87$

For 5 degrees of freedom and 95% confidence, $t_{table} = 2.571$.

Because $t_{calculated}$ (4.87) > t_{table} (2.571), the difference <u>is</u> significant.

S4-7. For Method 1, we find $\bar{x}_1 = 0.027\ 5_6$ and $s_1 = 0.000\ 4_{88}$.

For Method 2, $\bar{x}_2 = 0.026\ 9_0$ and $s_2 = 0.000\ 4_{06}$.

$F_{\text{calculated}} = 0.000\ 4_{88}{}^2/0.000\ 4_{06}{}^2 = 1._{44} < F_{\text{table}}$

$= 6.39$ (for 4 degrees of freedom in both the numerator and denominator).

Standard deviations are not significantly different at 95% confidence level.

Because $F_{\text{calculated}} < F_{\text{table}}$, we can use Equations 4-8 and 4-9.

$$s_{\text{pooled}} = \sqrt{\frac{s_1{}^2\ (n_1 - 1) + s_2{}^2\ (n_2 - 1)}{n_1 + n_2 - 2}}$$

$$= \sqrt{\frac{0.000\ 4_{88}{}^2\ (5-1) + 0.000\ 4_{06}{}^2\ (5-1)}{5+5-2}} = 0.000\ 4_{49}$$

$$t_{\text{calculated}} = \frac{\bar{x}_1 - \bar{x}_2}{s_{\text{pooled}}}\sqrt{\frac{n_1 n_2}{n_1 + n_2}} = \frac{0.027\ 5_6 - 0.026\ 9_0}{0.000\ 4_{49}}\sqrt{\frac{5 \cdot 5}{5+5}} = 2._{32}$$

Because $t_{\text{calculated}}$ (= $2._{32}$) > t_{table} (= 2.306 for 8 degrees of freedom), the difference is significant at the 95% confidence level.

S4-8. Sample 1: $\bar{x}_1 = 0.013\ 4_{00}$ $s_1 = 0.000\ 3_{937}$

Sample 2: $\bar{x}_2 = 0.013\ 9_{60}$ $s_2 = 0.000\ 3_{435}$

$F_{\text{calculated}} = 0.000\ 3_{937}{}^2 / 0.000\ 3_{435}{}^2 = 1._{314} < F_{\text{table}}$

$= 6.39$ (for 4 degrees of freedom in both the numerator and denominator).

Standard deviations are not significantly different at 95% confidence level.

Because $F_{\text{calculated}} < F_{\text{table}}$, we can use Equations 4-8 and 4-9.

$$s_{\text{pooled}} = \sqrt{\frac{4s_1^2 + 4s_2^2}{5+5-2}} = 0.000\ 3_{695}$$

$$t_{\text{calculated}} = \frac{0.013\ 960 - 0.013\ 400}{0.000\ 3_{695}}\sqrt{\frac{5 \cdot 5}{5+5}}$$

$= 2._{40} > 2.306$ (Student's t for 8 degrees of freedom) The difference is significant.

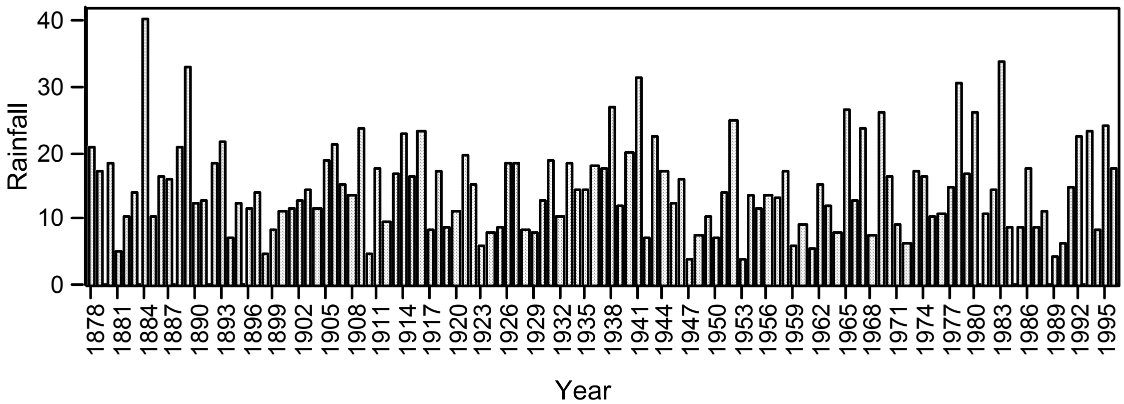
S4-9. $t = \dfrac{255 - 238}{14}\sqrt{\dfrac{4 \cdot 5}{4+5}} = 1.8_1 < 2.365$ (Student's t for 7 degrees of freedom)

Difference is not significant.

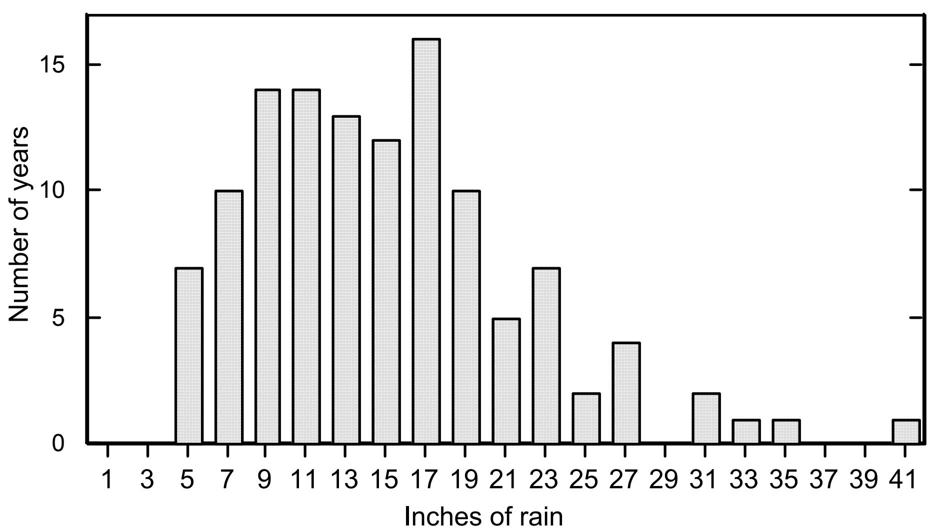
S4-10. $Q = (0.217 - 0.195) / (0.224 - 0.195) = 0.76 > 0.56$. Discard 0.195.

S4-11. (a) average = 15.01 standard deviation = 6.89

(b)



(c)



The distribution does not look Gaussian at all.

S4-12. The formula mass of $CuCO_3$ is 123.555 and Cu in this formula is 51.43 wt %. For the 1995 class data, the 95% confidence interval is

$$\mu\,(95\%) = \bar{x} \pm \frac{ts}{\sqrt{n}} = 55.6 \pm \frac{(2.02)(2.7)}{\sqrt{43}} = 55.6 \pm 0.8 = 54.8 \text{ to } 56.4 \text{ wt \%}$$

The 99% confidence interval is

$$\mu\,(99\%) = \bar{x} \pm \frac{ts}{\sqrt{n}} = 55.6 \pm \frac{(2.70)(2.7)}{\sqrt{43}} = 55.6 \pm 1.1 = 54.5 \text{ to } 56.7 \text{ wt \%}$$

Even the 99% confidence interval does not include the Cu content in $CuCO_3$ (51.43 wt %). From the 1996 class data, the 99% confidence interval is 54.3 to 57.5 wt %. From the instructor's measurements, the 99% confidence interval is 55.2 to 56.4 wt %. The product cannot be $CuCO_3$. It cannot be a hydrate either, because $CuCO_3 \cdot xH_2O$, would have an even lower Cu content than 51.43%. The observed composition is closer to that of the minerals azurite, $Cu_3(OH)_2(CO_3)_2$ (55.31 wt % Cu), or malachite, $Cu_2(OH)_2(CO_3)$ (57.48 wt % Cu), than it is to $CuCO_3$.