CHAPTER 1: SUPPLEMENTARY PROBLEMS
MEASUREMENTS

S1-1. Write the following quantities in exponential notation, with one digit to the left of the decimal point (e.g., 17 fC = 1.7×10^{-14} C):

(a) 2 TJ
(b) 37 mm
(c) 37 Mm
(d) 4 dK
(e) 842 pF
(f) 18.4 kPa

S1-2. Express the following quantities with abbreviations for units and prefixes from Tables 1-1 through 1-3:

(a) 8×10^{-5} moles
(b) 1×10^{10} watts
(c) 4×10^{-7} liters
(d) 3×10^{-2} meters
(e) 1.8×10^{14} hertz
(f) 537×10^{10} ohms

S1-3. The lowest temperature attained in the laboratory in 1990 was 800 pK (for the nuclei of silver atoms). Solid ^{3}He has been cooled to 43 μK. Express the quotient 800 pK/43 μK in exponential notation (i.e. $a \times 10^b$).

S1-4. Use Table 1-4 to confirm that there are 760 torr in 1 atm.

S1-5. If 0.250 L of aqueous solution with a density of 1.00 g/mL contins 13.7 μg of pesticide, express the concentration of pesticide in (a) ppm and (b) ppb.

S1-6. High purity water required in the semiconductor industry is purified by a process called deionization in which most cations and anions are replaced by H^+ and OH^-, respectively. (The product of $H^+ + OH^-$ is just H_2O.) The average concentrations of some residual cations and anions left after deionization in one high purity industrial water line are shown below:

Na^+	154 ng/L	Cl^-	172 ng/L
NH_4^+	58 ng/L	Br^-	<10 ng/L
K^+	63 ng/L	NO_3^-	26 ng/L
Mg^{2+}	73 ng/L	HPO_4^{2-}	<30 ng/L
Ca^{2+}	45 ng/L	SO_4^{2-}	128 ng/L

Find the molar concentrations of Na^+ and Cl^- in this water.
Use a prefix from Table 1-3 to express your answers.

S1-7. Find the molarity of pyridine (C_5H_5N) if 5.00 g is dissolved in butanol to give a total volume of 457 mL.

S1-8. A 95.0 wt % solution of ethanol (CH_3CH_2OH, FM 46.07) in water has a density of 0.804 g/mL.

(a) Find the mass of 1.00 L of this solution and the number of grams of ethanol per liter.

(b) What is the molar concentration of ethanol in this solution?

(c) Find the molality of ethanol in this solution, considering H_2O to be the solvent (even though H_2O is really the solute in this case).

S1-9. (a) How many grams of the element nickel are contained in 10.0 g of a 10.2 wt % solution of nickel sulfate hexahydrate, $NiSO_4 \cdot 6H_2O$ (FM 262.85)?

(b) The concentration of this solution is 0.412 M. Find the density.

S1-10. Describe how to prepare exactly 100 mL of 1.00 M HCl from 12.1 M HCl reagent.

S1-11. Describe how to prepare approximately 100 mL of 0.082 *m* $NaClO_4$ (FM 122.44).

S1-12. A 40.0 wt % solution of CsCl (FM 168.37) has a density of 1.43 g/mL, while a 20.0 wt % solution has a density of 1.18 g/mL.

(a) Find the molarity of CsCl in each solution.

(b) Find the molality of CsCl in each solution.

(c) How many mL of each solution should be diluted to 500 mL to make 0.100 M reagent? Why doesn't it take twice as much of the 20.0 wt % solution as the 40.0 wt % solution?

S1-13. How many grams and how many mL of 40.0 wt % urea solution (density = 1.111 g/mL) are required to react with 4.00 mmol of Fe^{3+} in the following reactions?

$$\underset{\text{Urea}}{(H_2N)_2CO} + 3H_2O \rightarrow CO_2 + 2NH_4^+ + 2OH^-$$

$$Fe^{3+} + 3OH^- + (x-1)H_2O \rightarrow FeOOH \cdot xH_2O(s)$$

S1-14. The constant ħ (read "h bar") is defined as $h/2\pi$, where h is Planck's constant [6.626 075 5 (±0.000 004 0) $\times 10^{-34}$ J·s]. Calculate the value and absolute uncertainty of ħ. The number 2 is an integer (infinitely accurate) and π is also an exact number. The first 10 digits of π are 3.141 592 653.

TOOLS OF THE TRADE

S2-1. Find the true mass of benzene (C_6H_6, density = 0.88 g/mL) if the apparent mass in air is 9.947 g. Assume that the air density is 0.001 2 g/mL and the balance weight density is 8.0 g/mL.

S2-2. An aqueous solution prepared when the lab temperature was 19° C had a concentration 0.027 64 M. What is the concentration of the same solution when used outdoors in the summer at 35° C?

S2-3. Water from a 5-mL pipet was drained into a weighing bottle whose empty mass was 9.974 g to give a new mass of 14.974 g at 26° C. Find the volume of the pipet at 26° C and at 20° C.

CHAPTER 3: SUPPLEMENTARY PROBLEMS
EXPERIMENTAL ERROR

S3-1. Indicate how many significant figures there are in:

(a) 0.305 0 (b) 0.003 050 (c) 1.003×10^4

S3-2. Round each number as indicated:

(a) 5.124 8 to 4 significant figures
(b) 5.124 4 to 4 significant figures
(c) 5.124 5 to 4 significant figures
(d) 0.135 237 1 to 4 significant figures
(e) 1.525 to 3 significant figures
(f) 1.525 007 to 3 significant figures

S3-3. Write each answer with the correct number of digits:

(a) $3.021 + 8.99 = 12.011$
(b) $12.7 - 1.83 = 10.87$
(c) $6.345 \times 2.2 = 13.959\,0$
(d) $0.030\,2 \div (2.114\,3 \times 10^{-3}) = 14.283\,69$
(e) $\log (2.2 \times 10^{-18}) = ?$
(f) $\text{antilog} (-2.224) = ?$
(g) $10^{-4.555} = ?$

S3-4. Using the correct number of significant figures, find the formula mass of $C_6H_{13}B$.

S3-5. Find the absolute and percent relative uncertainty and express each answer with a reasonable number of significant figures.

(a) $3.4 (\pm 0.2) + 2.6 (\pm 0.1) = ?$
(b) $3.4 (\pm 0.2) \div 2.6 (\pm 0.1) = ?$
(c) $[3.4 (\pm 0.2) \times 10^{-8}] \div [2.6 (\pm 0.1) \times 10^3] = ?$
(d) $[3.4 (\pm 0.2) - 2.6 (\pm 0.1)] \times 3.4 (\pm 0.2) = ?$

S3-6. Express the molecular mass (± uncertainty) of benzene, C_6H_6, with the correct number of significant figures.

S3-7. (a) A solution is prepared by dissolving 0.222 2 (±0.000 2) g of KIO_3 [FM 214.001 0 (±0.000 9)] in 50.00 (±0.05) mL. Find the molarity and its uncertainty with an appropriate number of significant figures.

(b) Would the answer be affected significantly if the reagent were only 99.9% pure?

S3-8. Find the absolute and percent relative uncertainty and express each answer with a reasonable number of significant figures.

(a) $\sqrt{3.4 (\pm 0.2)} = ?$
(b) $[3.4 (\pm 0.2)]^2 = ?$
(c) $10^{3.4 (\pm 0.2)} = ?$
(d) $e^{3.4 (\pm 0.2)} = ?$
(e) $\log [3.4 (\pm 0.2)] = ?$
(f) $\ln [3.4 (\pm 0.2)] = ?$

S3-9. The value of Boltzmann's constant (*k*) listed on the inside front cover of the book is calculated from the quotient *R*/*N*, where *R* is the gas constant and *N* is Avogadro's number. If the uncertainty in *R* is 0.000 070 J/(mol · K) and the uncertainty in *N* is $0.000\,003\,6 \times 10^{23}$/mol, find the uncertainty in *k*.

S3-10. Find the uncertainty in the molecular mass of $B_{10}H_{14}$ and write the molecular mass with the correct number of significant figures.

CHAPTER 4: SUPPLEMENTARY PROBLEMS
EXPERIMENTAL ERROR

S4-1. Consider Rayleigh's data for the mass of gas from air in Table 4-3. Find the
(a) mean (b) standard deviation (c) variance

S4-2. Suppose that a Gaussian population of measurements has a mean of 1 000 and a standard deviation of 50. What fraction of the population lies in the following intervals:
(a) >1 000 (b) 950-1 050 (c) 850-1 150
(d) <900 (e) 930-1 030 (f) 912-991

S4-3. Write the equation of the smooth Gaussian curve in Figure 4-1. (Since the curve represents the results of 4 768 measurements, and each bar on the graph corresponds to a 20-h interval, you must use a factor of 4 768 × 20 in the numerator of Equation 4-3.) Use the equation to calculate the value of y when $x = 1000$ h and see if your calculated value agrees with the value on the graph.

S4-4. Find the 95 and 99% confidence intervals for the mean mass of nitrogen from chemical sources in Table 4-3.

S4-5. Two methods were used to measure the specific activity (units of enzyme activity per milligram of protein) of an enzyme. One unit of enzyme activity is defined as the amount of enzyme that catalyzes the formation of one micromole of product per minute under specified conditions.

Enzyme activity (five replications)

Method 1:	139	147	160	158	135
Method 2:	148	159	156	164	159

Is the mean value of method 1 significantly different from the mean value of method 2 at the 95% confidence level?

S4-6. It is known from many careful measurements that the concentration of magnesium in a material is 0.137 wt %. Your new analytical procedure gives values of 0.129, 0.133, 0.136, 0.130, 0.128 and 0.131 wt %. Do your results differ from the expected result at the 95% confidence level?

S4-7. Calcium in a mineral was analyzed five times by each of two methods, with similar standard deviations. Are the mean values significantly different at the 95% confidence level?

Method 1:	0.027 1	0.028 2	0.027 9	0.027 1	0.027 5
Method 2:	0.027 1	0.026 8	0.026 3	0.027 4	0.026 9

S4-8. The Ti content (wt %) of two different ore samples was measured several times by the same method. Are the mean values significantly different at the 95% confidence level?

Sample 1:	0.013 4	0.013 8	0.012 8	0.013 3	0.013 7
Sample 2:	0.013 5	0.014 2	0.013 7	0.014 1	0.014 3

S4-9. The calcium content of a person's urine was determined on two different days:

Day	Average Ca (mg/L)	Number of measurements
1	238	4
2	255	5

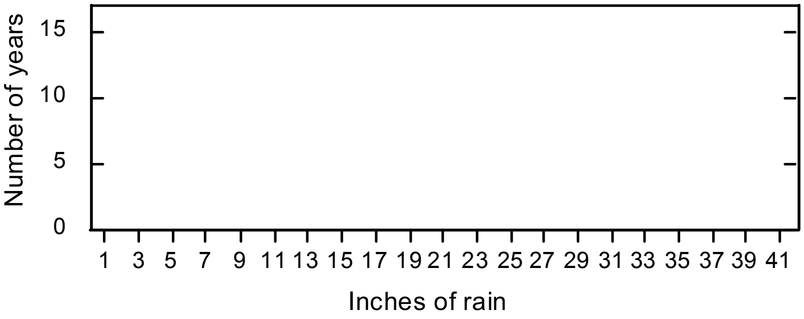
The analysis applied to many samples yields a standard deviation of 14 mg/L. Are the two averages significantly different at the 95% confidence level?

S4-10. Using the *Q* test, decide whether the value 0.195 should be rejected from the set of results: 0.217, 0.224, 0.195, 0.221, 0.221, 0.223.

S4-11. (a) The table below lists rainfall measured in Los Angeles. Enter this data into a spreadsheet and compute the average and standard deviation.

(b) Prepare a barchart showing rainfall as a function of year from 1878 to 1996.

(c) Prepare a *histogram* (another barchart) from this data showing rainfall in 2-inch intervals in the format below. For example, the bar at $x = 15$ will show the number of years in which the rainfall was in the range 14.00 to 15.99 inches. In your judgement, does rainfall follow a Gaussian distribution?



Year	Rainfall (inches)	Year	Rainfall (inches)	Year	Rainfall (inches)
1878	20.860	1918	17.490	1958	17.490
1879	17.410	1919	8.820	1959	6.230
1880	18.650	1920	11.180	1960	9.570
1881	5.530	1921	19.850	1961	5.830
1882	10.740	1922	15.270	1962	15.370
1883	14.140	1923	6.250	1963	12.310
1884	40.290	1924	8.110	1964	7.980
1885	10.530	1925	8.940	1965	26.810
1886	16.720	1926	18.560	1966	12.910
1887	16.020	1927	18.630	1967	23.660
1888	20.820	1928	8.690	1968	7.580
1889	33.260	1929	8.320	1969	26.320
1890	12.690	1930	13.020	1970	16.540
1891	12.840	1931	18.930	1971	9.260
1892	18.720	1932	10.720	1972	6.540
1893	21.960	1933	18.760	1973	17.450
1894	7.510	1934	14.670	1974	16.690
1895	12.550	1935	14.490	1975	10.700
1896	11.800	1936	18.240	1976	11.010
1897	14.280	1937	17.970	1977	14.970
1898	4.830	1938	27.160	1978	30.570
1899	8.690	1939	12.060	1979	17.000
1900	11.300	1940	20.260	1980	26.330
1901	11.960	1941	31.280	1981	10.920
1902	13.120	1942	7.400	1982	14.410
1903	14.770	1943	22.570	1983	34.040
1904	11.880	1944	17.450	1984	8.900
1905	19.190	1945	12.780	1985	8.920
1906	21.460	1946	16.220	1986	18.000
1907	15.300	1947	4.130	1987	9.110
1908	13.740	1948	7.590	1988	11.570
1909	23.920	1949	10.630	1989	4.560
1910	4.890	1950	7.380	1990	6.490
1911	17.850	1951	14.330	1991	15.070
1912	9.780	1952	24.950	1992	22.650
1913	17.170	1953	4.080	1993	23.440
1914	23.210	1954	13.690	1994	8.690
1915	16.670	1955	11.890	1995	24.060
1916	23.290	1956	13.620	1996	17.750
1917	8.450	1957	13.240		

S4-12. Students at Eastern Illinois University intended to prepare copper(II) carbonate by adding a solution of $CuSO_4 \cdot 5H_2O$ to a solution of Na_2CO_3.

$$CuSO_4{\cdot}5H_2O(aq) + Na_2CO_3(aq) \rightarrow \underset{\text{copper(II) carbonate}}{CuCO_3(s)} + Na_2SO_4(aq) + 5H_2O(l)$$

After warming the mixture to 60°C, the gelatinous blue precipitate coagulated into an easily filterable pale green solid. The product was filtered, washed, and dried at 70° C. Copper in the product was measured by heating 0.4 g of solid in a stream of methane at high temperature to reduce the solid to pure Cu, which was weighed.

$$4CuCO_3(s) + CH_4(g) \xrightarrow{\text{heat}} 4Cu(s) + 5CO_2(g) + 2H_2O(g)$$

In 1995, 43 students found a mean value of 55.6 wt % Cu with a standard deviation of 2.7 wt %. In 1996, 39 students found 55.9 wt % with a standard deviation of 3.8 wt %. The instructor tried the experiment 9 times and measured 55.8 wt % with a standard deviation of 0.5 wt %. Was the product of the reaction probably $CuCO_3$? Could it have been a hydrate, $CuCO_3 \cdot xH_2O$? [This problem was taken from D. Sheeran, *J. Chem. Ed*. **1998**, *75*, 453. See also H. Gamsjäger and W. Preis, *J. Chem. Ed*. **1999**, *76*, 1339.]