Mean => $\overline{x} = \dfrac{\sum_i x_i}{n}$ **standard deviation =>** $s = \sqrt{\dfrac{\sum_i (x_i - \overline{x})^2}{n-1}}$

Confidence interval: $\mu = \overline{x} \pm \dfrac{ts}{\sqrt{n}}$ $\%e = \dfrac{e}{\overline{X}} \cdot 100$

$\pm t = (\overline{x} - \mu)\left(\dfrac{\sqrt{n}}{s}\right)$ CASE 1

$t = \dfrac{|\overline{x}_1 - \overline{x}_2|}{s_{spooled}} \sqrt{\dfrac{n_1 n_2}{n_1 + n_2}}$ $s_{spooled} = \sqrt{\dfrac{s_1^2(n_1-1) + s_2^2(n_2-1)}{n_1 + n_2 - 2}}$ CASE 2

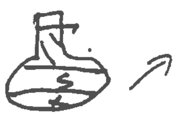
$t = \dfrac{\overline{d}}{s_d}\sqrt{n}$ $s_d = \sqrt{\dfrac{\sum_i (d_i - \overline{d})^2}{n-1}}$

$Q = \dfrac{gap}{range}$ $F = \dfrac{s_1^2}{s_2^2}$ $e_f = \sqrt{\sum_{i=1}^{n} e_i^2}$ $\% e_f = \sqrt{\sum_{i=1}^{n} \%e_i^2}$

$$\frac{\textbf{concentration ratio (x/s) in unknown}}{\textbf{concentration ratio in standard mixture}} = \frac{\textbf{signal ratio (x/s) in unknown}}{\textbf{signal ratio in standard mixture}}$$

INTERNAL STANDARD

$$\frac{[X]_i}{[X]_f + [S]_f} = \frac{[I]_x}{[I]_{x+s}}$$



$$\frac{[x]}{[IS]} \cdot F = \frac{I_x}{I_{IS}}$$

$A = \log_{10}(P_o/P) = -\log_{10} T$

Grating Equation: $n\lambda = d(\sin\theta - \sin\phi)$

$A = \varepsilon\ b\ C$ $C = \lambda\ \nu,$

$E = h\nu$ $E = (-2.178 \times 10^{-18}\ J) * (z^2/n^2)$

$N = \dfrac{16\ t_r^2}{w^2}$ or $\dfrac{5.55\ t_r^2}{w_{1/2}^2}$ $R = \dfrac{\Delta t_r}{w_{av}}$

TABLE 3-1 Summary of rules for propagation of uncertainty

Function	Uncertainty	Function[a]	Uncertainty[b]
$y = x_1 + x_2$	$e_y = \sqrt{e_{x_1}^2 + e_{x_2}^2}$	$y = x^a$	$\%e_y = a\%e_x$
$y = x_1 - x_2$	$e_y = \sqrt{e_{x_1}^2 + e_{x_2}^2}$	$y = \log x$	$e_y = \frac{1}{\ln 10}\frac{e_x}{x} \approx 0.434\,29\frac{e_x}{x}$
$y = x_1 \cdot x_2$	$\%e_y = \sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$	$y = \ln x$	$e_y = \frac{e_x}{x}$
$y = \frac{x_1}{x_2}$	$\%e_y = \sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$	$y = 10^x$	$\frac{e_y}{y} = (\ln 10)e_x \approx 2.302\,6\, e_x$
		$y = e^x$	$\frac{e_y}{y} = e_x$

a. x represents a variable and a represents a constant that has no uncertainty.
b. e_x/x is the relative error in x and $\%e_x$ is $100 \times e_x/x$.

Harris, *Quantitative Chemical Analysis*, 8e

general: $e_f = \sqrt{\sum_i \left(\frac{\partial f}{\partial x_i}\right)^2 \cdot e_i^2}$

TABLE 4-2 Values of Student's t

Degrees of freedom	Confidence level (%)						
	50	90	95	98	99	99.5	99.9
1	1.000	6.314	12.706	31.821	63.656	127.321	636.578
2	0.816	2.920	4.303	6.965	9.925	14.089	31.598
3	0.765	2.353	3.182	4.541	5.841	7.453	12.924
4	0.741	2.132	2.776	3.747	4.604	5.598	8.610
5	0.727	2.015	2.571	3.365	4.032	4.773	6.869
6	0.718	1.943	2.447	3.143	3.707	4.317	5.959
7	0.711	1.895	2.365	2.998	3.500	4.029	5.408
8	0.706	1.860	2.306	2.896	3.355	3.832	5.041
9	0.703	1.833	2.262	2.821	3.250	3.690	4.781
10	0.700	1.812	2.228	2.764	3.169	3.581	4.587
15	0.691	1.753	2.131	2.602	2.947	3.252	4.073
20	0.687	1.725	2.086	2.528	2.845	3.153	3.850
25	0.684	1.708	2.060	2.485	2.787	3.078	3.725
30	0.683	1.697	2.042	2.457	2.750	3.030	3.646
40	0.681	1.684	2.021	2.423	2.704	2.971	3.551
60	0.679	1.671	2.000	2.390	2.660	2.915	3.460
120	0.677	1.658	1.980	2.358	2.617	2.860	3.373
∞	0.674	1.645	1.960	2.326	2.576	2.807	3.291

In calculating confidence intervals, σ may be substituted for s in Equation 4-6 if you have a great deal of experience with a particular method and have therefore determined its "true" population standard deviation. If σ is used instead of s, the value of t to use in Equation 4-6 comes from the bottom row of Table 4-2.

Values of t in this table apply to two-tailed tests illustrated in Figure 4-9a. The 95% confidence level specifies the regions containing 2.5% of the area in each wing of the curve. For a one-tailed test, we use values of t listed for 90% confidence. Each wing outside of t for 90% confidence contains 5% of the area of the curve.

Harris, *Quantitative Chemical Analysis*, 8e

TABLE 4-5 Critical values of G for rejection of outlier

Number of observations	G (95% confidence)
4	1.463
5	1.672
6	1.822
7	1.938
8	2.032
9	2.110
10	2.176
11	2.234
12	2.285
15	2.409
20	2.557

$G_{calculated}$ = |questionable value − mean|/s. If $G_{calculated} > G_{table}$, the value in question can be rejected with 95% confidence. Values in this table are for a one-tailed test, as recommended by ASTM.

SOURCE: *ASTM E 178-02 Standard Practice for Dealing with Outlying Observations, http://webstore.ansi.org; F. E. Grubbs and G. Beck, Technometrics* **1972**, *14, 847.*

$$G_{CAL} = \frac{|out - \bar{x}|}{s}$$

Harris, *Quantitative Chemical Analysis*, 8e

Periodic Table

Atomic Number — 22
Boiling point (K) — 3562
Melting point (K) — 1943
Density at 300 K (g /cm^3) — 4.5
(Densities marked with ¤ are at 273 K and 1 atm and the units are g/L)
Ti — Titanium — 47.867
Oxidation states (Bold is most stable state) — +4,3
Atomic mass is accurate to ±1 in last decimal place unless otherwise indicated
Examples:
Ti = 47.867 ± 0.001
Fe = 55.845 ± 0.002

[Atomic masses from *Pure Appl. Chem.* 1996, *68*, 2339]

1	2	3	4	5	6	7	8	9
1 H +1 20.268 14.025 0.0899¤ Hydrogen 1.007 94 ±7								
3 Li +1 1615 454 0.53 Lithium 6.941 ±2†	4 Be +2 2745 1560 1.85 Beryllium 9.012 182 ±3							
11 Na +1 1156 371 0.97 Sodium 22.989 770 ±2	12 Mg +2 1363 922 1.74 Magnesium 24.305 0 ±6							
19 K +1 1032 336 0.86 Potassium 39.098 3	20 Ca +2 1757 1112 1.55 Calcium 40.078 ±4	21 Sc +3 3104 1812 3.0 Scandium 44.955 910 ±8	22 Ti +4,3 3562 1943 4.5 Titanium 47.867	23 V +5,4,3,2 3682 2175 5.8 Vanadium 50.941 5	24 Cr +6,3,2 2945 2130 7.19 Chromium 51.996 1 ±6	25 Mn +7,6,4,2,3 2335 1517 7.43 Manganese 54.938 049 ±9	26 Fe +2,3 3135 1809 7.86 Iron 55.845 ±2	27 Co +2,3 3201 1768 8.90 Cobalt 58.933 200 ±9
37 Rb +1 961 313 1.53 Rubidium 85.467 8 ±3	38 Sr +2 1650 1041 2.6 Strontium 87.62	39 Y +3 3611 1799 4.5 Yttrium 88.905 85 ±2	40 Zr +4 4682 2125 6.49 Zirconium 91.224 ±2	41 Nb +5,3 5017 2740 8.55 Niobium 92.906 38 ±2	42 Mo +6,5,4,3,2 4912 2890 10.2 Molybdenum 95.94	43 Tc +7 4538 2473 11.5 Technetium (99)	44 Ru +2,3,4,6,8 4423 2523 12.2 Ruthenium 101.07 ±2	45 Rh +2,3,4 3970 2236 12.4 Rhodium 102.905 50 ±2
55 Cs +1 944 302 1.87 Cesium 132.905 45 ±2	56 Ba +2 2171 1002 3.5 Barium 137.327 ±7	57 La +3 3730 1193 6.7 Lanthanum 138.905 5 ±2	72 Hf +4 4876 2500 13.1 Hafnium 178.49 ±2	73 Ta +5 5731 3287 16.6 Tantalum 180.947 9	74 W +6,5,4,3,2 5828 3680 19.3 Tungsten 183.84	75 Re +7,6,4,2,-1 5869 3453 21.0 Rhenium 186.207	76 Os +2,3,4,6,8 5285 3300 22.4 Osmium 190.23 ±3	77 Ir +2,3,4,6 4701 2716 22.5 Iridium 192.217±3
87 Fr +1 950 300 — Francium (223)	88 Ra +2 1809 973 5 Radium (226)	89 Ac +3 3473 1323 10.07 Actinium (227)	104 Rf — — — Rutherfordium (261)	105 Db — — — Dubnium (262)	106 Sg — — — Seaborgium (266)	107 Bh — — — Bohrium (262)	108 Hs — — — Hassium (265)	109 Mt — — — Meitnerium (266)

†Commercial lithium compounds are artificially depleted of ^{6}Li. The atomic mass of commercial Li is in the range 6.94 - 7.00. [H. P. Qi, T. B. Coplen, Q. Z. Wang and Y. H. Wang, *Anal. Chem.* 1997, *69*, 4076.]

58 Ce +3,4 3699 1071 6.78 Cerium 140.116	59 Pr +3,4 3785 1204 6.77 Praseodymium 140.907 65 ±2	60 Nd +3 3341 1289 7.00 Neodymium 144.24 ±3	61 Pm +3 3785 1204 6.48 Promethium (145)	62 Sm +3,2 2064 1345 7.54 Samarium 150.36 ±3	63 Eu +3,2 1870 1090 5.26 Europium 151.964
90 Th +4 5061 2028 11.7 Thorium 232.038 1	91 Pa +5,4 — — 15.4 Protactinium 231.035 88 ±2	92 U +6,5,4,3 4407 1405 18.90 Uranium 238.028 9	93 Np +6,5,4,3 — 910 20.4 Neptunium 237.048 2	94 Pu +6,5,4,3 3503 913 19.8 Plutonium (244)	95 Am +6,5,4,3 2880 1268 13.6 Americium (243)

Rupnue

Of The Elements

10	11	12	13	14	15	16	17	18
								2 He 4.215 0.95 0.179¤ Helium 4.002 602 ±2
			5 +3 B 4275 2300 2.34 Boron 10.811 ±7	6 ±4,2 C 4470 4100 2.62 Carbon 12.010 7 ±8	7 ±3,5,4,2 N 77.35 63.14 1.251¤ Nitrogen 14.006 74 ±7	8 -2 O 90.18 50.35 1.429¤ Oxygen 15.999 4 ±3	9 -1 F 84.95 53.48 1.696¤ Fluorine 18.998 403 2 ±5	10 Ne 27.10 24.55 0.901¤ Neon 20.179 7 ±6
			13 +3 Al 2793 933.25 2.7 Aluminum 26.981 538 ±2	14 +4 Si 3540 1685 2.33 Silicon 28.085 5 ±3	15 ±3,5,4 P 550 317.3 1.82 Phosphorus 30.973 761 ±2	16 ±2,4,6 S 717.8 388.4 2.07 Sulfur 32.066 ±6	17 ±1,3,5,7 Cl 239.1 172.2 3.17¤ Chlorine 35.452 7 ±9	18 Ar 87.3 83.81 1.784¤ Argon 39.948
28 +2,3 Ni 3187 1726 8.90 Nickel 58.693 4 ±2	29 +2,1 Cu 2836 1358 8.96 Copper 63.546 ±3	30 +2 Zn 1180 693 7.14 Zinc 65.39 ±2	31 +3 Ga 2478 303 5.91 Gallium 69.723	32 +4 Ge 3107 1210 5.32 Germanium 72.61 ±2	33 ±3,5 As 876 5.72 Arsenic 74.921 60 ±2	34 -2,4,6 Se 958 494 4.80 Selenium 78.96 ±3	35 ±1,5 Br 332.25 265.90 3.12 Bromine 79.904	36 Kr 119.80 115.78 3.74¤ Krypton 83.80
46 +2,4 Pd 3237 1825 12.0 Palladium 106.42	47 +1 Ag 2436 1234 10.5 Silver 107.868 2 ±2	48 +2 Cd 1040 594 8.65 Cadmium 112.411 ±8	49 +3 In 2346 430 7.31 Indium 114.818 ±3	50 +4,2 Sn 2876 505 7.30 Tin 118.710 ±7	51 ±3,5 Sb 1860 904 6.68 Antimony 121.760	52 -2,4,6 Te 1261 723 6.24 Tellurium 127.60 ±3	53 ±1,5,7 I 458 387 4.92 Iodine 126.904 47 ±3	54 Xe 165 161 5.89¤ Xenon 131.29 ±2
78 +2,4 Pt 4100 2045 21.4 Platinum 195.078 ±2	79 +3,1 Au 3130 1338 19.3 Gold 196.966 55 ±2	80 +2,1 Hg 630 234 13.5 Mercury 200.59 ±2	81 +3,1 Tl 1746 577 11.85 Thallium 204.383 3 ±2	82 +4,2 Pb 2023 601 11.4 Lead 207.2	83 +3,5 Bi 1837 545 9.8 Bismuth 208.980 38 ±2	84 +4,2 Po 1235 527 9.4 Polonium (~210)	85 ±1,3,5,7 At 610 575 — Astatine (~210)	86 Rn 211 202 9.91¤ Radon (~222)

64 +3 Gd 3539 1585 7.89 Gadolinium 157.25 ±3	65 +3 Tb 3496 1630 8.27 Terbium 158.925 34 ±2	66 +3 Dy 2835 1682 8.54 Dysprosium 162.50 ±3	67 +3 Ho 2968 1743 8.80 Holmium 164.930 32 ±2	68 +3 Er 3136 1795 9.05 Erbium 167.26 ±3	69 +3,2 Tm 2220 1818 9.33 Thulium 168.934 21 ±2	70 +3,2 Yb 1467 1097 6.98 Ytterbium 173.04 ±3	71 +3 Lu 3668 1936 9.84 Lutetium 174.967
96 +3 Cm — 1340 13.51 Curium (247)	97 +4,3 Bk — — — Berkelium (247)	98 +3 Cf — 900 — Californium (251)	99 Es — — — Einsteinium (254)	100 Fm — — — Fermium (257)	101 Md — — — Mendelevium (260)	102 No — — — Nobelium (259)	103 Lr — — — Lawrencium (262)