# NATIONAL UNIVERSITY OF LESOTHO

## Faculty of Science and Technology

## Department of Chemistry and Chemical Technology

#### B.Sc., B.Sc. CTech., B.Sc. Ed., B.Sc. Env. Sci. Supplementary Examination

#### C2620 - Analytical Chemistry I

August 2023	[Total Marks = 100]	Time allowed: 3 Hrs

#### Instructions:

- 1. This question paper consists of a total of seven (7) printed pages (including the cover page and data tables
- 2. There are four (4) main questions. Attempt all questions.
- 3. You may answer the questions in any order. However, **you must clearly indicate** the question you are attempting.
- 4. Begin each main question (i.e. Q1, Q2 etc.) on a new page.

[2 marks]

# Question 1 [13 marks]

a) Differentiate between the following pairs of terms:

i.	Analysis & Assay	[3 marks]
ii.	Procedure & Protocol	[3 marks]

- b) The concentration of dissolved O<sub>2</sub> in a lake shows a daily cycle due to the effect of photosynthesis and a yearly cycle due to seasonal changes in temperature.
  - Which of the following sampling plan will you use for monitoring the daily changes in dissolved O<sub>2</sub>: random, systematic, judgmental, systematic–judgmental, or stratified? [2 marks]
  - ii. Explain your answer to question (b, i) above [5 marks]

# Question 2 [35 marks]

#### a) Define the following terms:

- i. Sample [2 marks]
- ii. Bias
- b) Explain why changing all values in a data set by a constant amount will change the mean but will have no effect on the standard deviation.
   [6 marks]
- c) Using an old method, the determination of acetaminophen in 10 separate tablets of Excedrin Extra Strength Pain Reliever gives the following results (in mg)

224.3	240.4	246.3	239.4	253.1
261.7	229.4	255.5	235.5	249.7

Report the mean value of this data and express it as mean  $\pm$  standard deviation [10 marks]

d) When performing the analysis in question 2 (c) using a different new method, the following results (in mg) are obtained

223.4	239.2	244.3	238.9	243.1
249.7	229.9	245.5	239.5	242.7

Is the precision of the new method significantly different from that of the old method? [15 marks]

[8 marks]

## Question 3 [32 marks]

a) De	fine the following terms:	
i.	Formality	[3 marks]
ii.	Equivalent weight	[3 marks]
b) To	prepare a standard solution of ${\rm Mn}^{2+}$ a 1.250 g sample of ${\rm MnCl}_2$ is dissolved in	10.00 mL of concentrated
HN	$IO_3$ . The resulting solution is quantitatively transferred to a 100-mL volumetric fl	ask and diluted to volume
wit	th distilled water. A 10.00 mL aliquot of the solution is pipetted into a 500-mL vo	olumetric flask and diluted
to	volume. Express the concentration of Mn in	
i.	Molarity	[8 marks]

- ii. ppm
- c) A buffer is made of 0.015 M sodium formate (HCOONa) and 0.025 M formic acid ( $K_a = 1.77 \times 10^{-4}$ ) with a total volume of 100.00 mL. How many millilitres of 0.200M HCl can be added to this buffer before the buffer's pH changes by 1.00? [10 marks]

## Question 4 [20 marks]

- a) Given that the titration of 0.4512 g of primary standard potassium hydrogen phthalate KHP ( $KHC_8H_4O_4$ ) required 26.46 mL of  $Ba(OH)_2$ , calculate the molar concentration of  $Ba(OH)_2$ . [6 marks]
- b) The amount of protein in a sample of cheese is determined by a Kjeldahl analysis for nitrogen. After digesting a 1.9814-g sample of cheese, the nitrogen was oxidized to  $NH_4^+$ , converted to  $NH_3$  with NaOH, and distilled into a collection flask containing 50.00 mL of 0.5047 M HCl. The excess HCl was then back titrated with 0.2183 M NaOH, requiring 22.84 mL to reach the bromothymol blue end point. Report the %w/w protein in the cheese, given that there is 6.38 g of protein for every gram of nitrogen in most dairy products. [8 marks]
- c) The reduction of iron by iodine is represented by the following <u>unbalanced</u> redox reaction

 $Fe^{3+} + I^{-} \implies Fe^{2+} + I_{3}^{-}$ 

Balance the reaction equation and determine the equilibrium constant (K<sub>eq</sub>) for this reaction [6 marks]

#### **Useful Data Tables**

<b>Ν</b> /α	0.1	0.05	0.04	0.02	0.01
3	0.941	0.970	0.976	0.988	0.994
4	0.765	0.829	0.846	0.889	0.926
5	0.642	0.710	0.729	0.780	0.821
6	0.560	0.625	0.644	0.698	0.740
7	0.507	0.568	0.586	0.637	0.680
8	0.468	0.526	0.543	0.590	0.634
9	0.437	0.493	0.510	0.555	0.598
10	0.412	0.466	0.483	0.527	0.568

## Table 1: Critical values for Q-Test

#### Table 2: t-table<sup>a</sup>

alue of t for confidence interval of:	90%	95%	<b>98</b> %	99%
Critical value of $ t $ for $\alpha$ values of:	0.10	0.05	0.02	0.01
Degrees of Freedom				
1	6.31	12.71	31.82	63.66
2	2.92	4.30	6.96	9.92
3	2.35	3.18	4.54	5.84
4	2.13	2.78	3.75	4.60
5	2.02	2.57	3.36	4.03
6	1.94	2.45	3.14	3.71
7	1.89	2.36	3.00	3.50
8	1.86	2.31	2.90	3.36
9	1.83	2.26	2.82	3.25
10	1.81	2.23	2.76	3.17
12	1.78	2.18	2.68	3.05
14	1.76	2.14	2.62	2.98
16	1.75	2.12	2.58	2.92
18	1.73	2.10	2.55	2.88
20	1.72	2.09	2.53	2.85
30	1.70	2.04	2.46	2.75
50	1.68	2.01	2.40	2.68
00	1.64	1.96	2.33	2.58

<sup>a</sup>The *t*-values in this table are for a two-tailed test. For a one-tailed test, the  $\alpha$  values for each column are half of the stated value. For example, the first column for a one-tailed test is for the 95% confidence level,  $\alpha = 0.05$ .

# Table 3: *F*-Table for One-Tailed Test at $\alpha$ = 0.05 (95% Confidence Level)

$v_2/v_1^a$	1	2	3.	4	5	6	7	8	9	10	15	20	~
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	245.9	248.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.43	19.45	19.50
3	10.13	9.552	9.277	9.117	9.013	8.941	8.887	8.845	8.812	8.786	8.703	8.660	8.526
4	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.999	5.964	5.858	5.803	5.628
5	6.608	5.786	5.409	5.192	5.050	4.950	4.876	4.818	4.772	4.735	4.619	4.558	4.365
6	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.099	4.060	3.938	3.874	3.669
7	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.677	3.637	3.511	3.445	3.230
8	5.318	4.459	4.066	3.838	3.687	3.581	3.500	3.438	3.388	3.347	3.218	3.150	2.928
9	5.117	4.256	3.863	3.633	3.482	3.374	3.293	3.230	3.179	3.137	3.006	2.936	2.707
10	4.965	4.103	3.708	3.478	3.326	3.217	3.135	3.072	3.020	2.978	2.845	2.774	2.538
11	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.896	2.854	2.719	2.646	2.404
12	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.796	2,753	2.617	2.544	2.296
13	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671	2.533	2.459	2.206
14	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602	2.463	2.388	2.131
15	4.534	3.682	3.287	3.056	2.901	2.790	2.707	2.641	2.588	2.544	2.403	2.328	2.066
16	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.538	2.494	2.352	2.276	2.010
17	4.451	3.592	3.197	2.965	2.810	2.699	3.614	2.548	2.494	2.450	2.308	2.230	1.960
18	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412	2.269	2.191	1.917
19	4.381	3.552	3.127	2.895	2.740	2.628	2.544	2.477	2.423	2.378	2.234	2.155	1.878
20	4.351	3,493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348	2.203	2.124	1.843
~~~	3.842	2.996	2.605	2.372	2.214	2.099	2.010	1.938	1.880	1.831	1.666	1.570	1.000

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 $av_1 =$  degrees of freedom in numerator;  $v_2 =$  degrees of freedom in denominator.

# Table 4: *F*-Table for Two-Tailed Test at $\alpha$ = 0.05 (95% Confidence Level)

1	2	3	4	5	6	7	8	9	10	15	20	00
647.8	799.5	864.2	899.6	921.8	937.1	948.2	956.7	963.3	968.6	984.9	993.1	1018
38.51	39.00	39.17	39.25	39.30	39.33	39.36	39.37	39.39	39.40	39.43	39.45	39.498
17.44	16.04	15.44	15.10	14.88	14.73	14.62	14.54	14.47	14.42	14.25	14.17	13.902
12.22	10.65	9.979	9.605	9.364	9.197	9.074	8.980	8.905	8.844	8.657	8.560	8.257
10.01	8.434	7.764	7.388	7.146	6.978	6.853	6.757	6.681	6.619	6.428	6.329	6.015
8.813	7.260	6.599	6.227	5.988	5.820	5.695	5.600	5.523	5.461	5.269	5.168	4.849
8.073	6.542	5.890	5.523	5.285	5.119	4.995	4.899	4.823	4.761	4.568	4.467	4.142
7.571	6.059	5.416	5.053	4.817	4.652	4.529	4.433	4.357	4.295	4.101	3.999	3.670
7.209	5.715	5.078	4.718	4.484	4.320	4.197	4.102	4.026	3.964	3.769	3.667	3.333
6.937	5.456	4.826	4.468	4.236	4.072	3.950	3.855	3.779	3.717	3.522	3.419	3.080
6.724	5.256	4.630	4.275	4.044	3.881	3.759	3.664	3.588	3.526	3.330	3.226	2.883
6.544	5.096	4,474	4.121	3.891	3.728	3.607	3.512	3.436	3.374	3.177	3.073	2.725
6.414	4.965	4.347	3.996	3.767	3.604	3.483	3.388	3.312	3.250	3.053	2.948	2.596
6.298	4.857	4.242	3.892	3.663	3.501	3.380	3.285	3.209	3.147	2.949	2.844	2.487
6.200	4.765	4.153	3.804	3.576	3.415	3.293	3.199	3.123	3.060	2.862	2.756	2.395
6.115	4.687	4.077	3.729	3.502	3.341	3.219	3.125	3.049	2.986	2.788	2.681	2.316
6.042	4.619	4.011	3.665	3.438	3.277	3.156	3.061	2.985	2.922	2.723	2.616	2.247
5.978	4.560	3.954	3.608	3.382	3.221	3.100	3.005	2,929	2.866	2.667	2.559	2.187
5.922	4.508	3.903	3.559	3.333	3.172	3.051	2.956	2.880	2.817	2.617	2.509	2.133
5.871	4.461	3.859	3.515	3.289	3.128	3.007	2.913	2.837	2.774	2.573	2.464	2.085
5.024	3.689	3.116	2.786	2.567	2.408	2.288	2.192	2.114	2.048	1.833	1.708	1.000
	1 647.8 38.51 17.44 12.22 10.01 8.813 8.073 7.571 7.209 6.937 6.724 6.544 6.414 6.298 6.200 6.115 6.042 5.978 5.922 5.871 5.024	2           647.8         799.5           38.51         39.00           17.44         16.04           12.22         10.65           10.01         8.434           8.813         7.260           8.073         6.542           7.571         6.059           7.209         5.715           6.937         5.456           6.724         5.256           6.544         5.096           6.414         4.965           6.298         4.857           6.200         4.765           6.115         4.687           6.042         4.619           5.978         4.560           5.922         4.508           5.871         4.461           5.024         3.689	2         3           647.8         799.5         864.2           38.51         39.00         39.17           17.44         16.04         15.44           12.22         10.65         9.979           10.01         8.434         7.764           8.813         7.260         6.599           8.073         6.542         5.890           7.571         6.059         5.416           7.209         5.715         5.078           6.937         5.456         4.826           6.724         5.256         4.630           6.544         5.096         4.474           6.414         4.965         4.347           6.298         4.857         4.242           6.200         4.765         4.153           6.115         4.687         4.011           5.978         4.560         3.954           5.922         4.508         3.903           5.871         4.461         3.859           5.024         3.689         3.116	2         3         4           647.8         799.5         864.2         899.6           38.51         39.00         39.17         39.25           17.44         16.04         15.44         15.10           12.22         10.65         9.979         9.605           10.01         8.434         7.764         7.388           8.813         7.260         6.599         6.227           8.073         6.542         5.800         5.523           7.571         6.059         5.416         5.053           7.209         5.715         5.078         4.718           6.937         5.456         4.826         4.468           6.724         5.256         4.630         4.275           6.544         5.096         4.474         3.996           6.298         4.857         4.242         3.892           6.200         4.765         4.153         3.804           6.115         4.687         4.011         3.655           5.978         4.560         3.954         3.608           5.922         4.508         3.903         3.559           5.871         4.461         3.859	2         3         4         5           647.8         799.5         864.2         899.6         921.8           38.51         39.00         39.17         39.25         39.30           17.44         16.04         15.44         15.10         14.88           12.22         10.65         9.979         9.605         9.364           10.01         8.434         7.764         7.388         7.146           8.813         7.260         6.599         6.227         5.988           8.073         6.542         5.890         5.523         5.285           7.571         6.059         5.416         5.053         4.171           7.209         5.715         5.078         4.718         4.484           6.937         5.456         4.826         4.648         4.236           6.724         5.256         4.630         4.275         3.691           6.414         4.965         4.347         3.996         3.767           6.298         4.857         4.242         3.891         3.663           6.200         4.765         4.153         3.804         3.576           6.115         4.687         4.077<	1         2         3         4         5         6           647.8         799.5         864.2         899.6         921.8         937.1           38.51         39.00         39.17         39.25         39.30         39.33           17.44         16.04         15.44         15.10         14.88         14.73           12.22         10.65         9.979         9.605         9.364         9.197           10.01         8.434         7.764         7.388         7.146         6.978           8.813         7.260         6.599         6.227         5.988         5.820           8.073         6.542         5.890         5.523         5.285         5.119           7.571         6.059         5.416         5.053         4.817         4.652           7.209         5.715         5.078         4.718         4.484         4.320           6.937         5.456         4.826         4.468         4.236         4.072           6.724         5.256         4.630         4.275         4.044         3.881           6.544         5.996         4.474         4.121         3.891         3.728           6.414<	1234567647.8799.5864.2899.6921.8937.1948.238.5139.0039.1739.2539.3039.3339.3617.4416.0415.4415.1014.8814.7314.6212.2210.659.9799.6059.3649.1979.07410.018.4347.7647.3887.1466.9786.8538.8137.2606.5996.2275.9885.2055.6958.0736.5425.8905.5235.2855.1194.9957.5716.0595.4165.0534.8174.6524.5297.2095.7155.0784.7184.4844.3204.1976.9375.4564.8264.4684.2364.0723.9506.5445.0964.4744.1213.8913.7283.6076.4144.9654.3473.9963.7673.6043.4836.2984.8574.2423.8923.6633.5013.3806.2004.7654.1533.8043.5763.4153.2936.1154.6874.0773.7293.5023.3413.2196.0424.6194.0113.6653.4383.2773.1565.9784.5083.9033.5593.3333.1723.0515.8714.4613.8593.5153.2893.1283.0075.9243.689<	12345678647.8799.5864.2899.6921.8937.1948.2956.738.5139.0039.1739.2539.3039.3339.3639.3717.4416.0415.4415.1014.8814.7314.6214.5412.2210.659.9799.6059.3649.1979.0748.98010.018.4347.7647.3887.1466.9786.8536.7578.8137.2606.5996.2275.9885.8205.6955.6008.0736.5425.8905.5235.2855.1194.9954.8997.5716.0595.4165.0534.8174.6524.5294.4337.2095.7155.0784.7184.4844.3204.1974.1026.9375.4564.8264.4684.2364.0723.9503.8556.7245.2564.6304.2754.0443.8813.7593.6646.5445.0964.4744.1213.8913.7283.6073.5126.4144.9654.3473.9963.7673.6043.4833.3886.2984.8574.2423.8923.6633.5013.3803.2856.2004.7654.1533.8043.5763.4153.2933.1996.1154.6874.0773.7293.5023.3413.2193.1256.042	123456789647.8799.5864.2899.6921.8937.1948.2956.7963.338.5139.0039.1739.2539.3039.3339.3639.3739.3917.4416.0415.4415.1014.8814.7314.6214.5414.4712.2210.659.9799.6059.3649.1979.0748.9808.90510.018.4347.7647.3887.1466.9786.8536.7576.6818.8137.2606.5996.2275.9885.8205.6955.6005.5238.0736.5425.8905.5235.2855.1194.9954.8994.8237.5716.0595.4165.0534.8174.6524.5294.4334.3577.2095.7155.0784.7184.4844.3204.1974.1024.0266.9375.4564.8264.4684.2364.0723.9503.8553.7796.7245.2564.6304.2754.0443.8113.7593.6643.5886.5445.0964.4744.1213.8913.7283.6073.5123.4366.4144.9654.3473.9963.7673.6443.8813.3783.2126.2984.8574.2423.8923.6633.5153.2833.2123.1093.1236.1544.6674.07	12345678910647.8799.5864.2899.6921.8937.1948.2956.7963.3968.638.5139.0039.1739.2539.3039.3339.3639.3739.3939.4017.4416.0415.4415.1014.8814.7314.6214.5414.4714.4212.2210.659.9799.6059.3649.1979.0748.9808.9058.84410.018.4347.7647.3887.1466.9786.8536.7576.6816.6198.8137.2606.5996.2275.9885.8205.6005.5235.4618.0736.5425.8905.5235.2855.1194.9954.8994.8234.7617.5716.0595.4165.0534.8174.6524.5294.4334.3574.2957.2095.7155.0784.7184.4844.3204.1974.1024.0263.9646.9375.4564.8264.4684.2364.1973.1253.7793.7176.7245.2564.6304.2754.0443.8813.7593.6643.5883.5266.5445.0964.4744.1213.8913.7283.6073.5123.4363.3746.7245.2564.6304.2753.6643.6833.5263.6013.2853.2093.147<	1234567891015647.8799.5864.2899.6921.8937.1948.2956.7963.3968.6984.938.5139.0039.1739.2539.3039.3339.3639.3739.3939.4039.4317.4416.0415.4415.1014.8814.7314.6214.5414.4714.4214.2512.2210.659.9799.6059.3649.1979.0748.9808.9058.8448.65710.018.4347.7647.3887.1466.9786.8536.7576.6816.6196.4288.8137.2606.5996.2275.9885.8205.6055.6005.5235.4615.2698.0736.5425.8905.5235.2855.1194.9954.8994.8234.7614.5687.5716.0595.4165.0534.8174.6524.5294.4334.3574.2954.1017.2095.7155.0784.7184.4844.3204.1974.1024.0263.9643.7696.9375.4564.8264.4684.2364.0723.9503.8553.7793.7173.5226.7245.2564.6304.2754.0443.8813.7593.6643.5883.3223.3336.5445.0964.4744.1213.8913.2883.3123.2503.05	123456789101520647.8799.5864.2899.6921.8937.1948.2956.7963.3968.6984.9993.138.5139.0039.1739.2539.3039.3339.3639.3739.3939.4039.4339.4517.4416.0415.4415.1014.8814.7314.6214.5414.4714.4214.2514.1712.2210.659.9799.6059.3649.1979.0748.9808.9058.8448.6578.55010.018.4347.7647.3887.1466.9786.8536.7576.6816.6196.4286.3298.8137.2606.5996.2275.9885.8205.6955.6005.5235.4615.2695.1688.0736.5425.8905.5235.2855.1194.9954.8994.8234.7614.5684.4677.5716.0595.4165.0534.8174.6524.5294.4334.3574.2954.1013.9967.2095.7155.0784.7184.4844.3204.1974.1024.0263.9643.7693.6676.9375.4564.8264.6723.9503.8553.7793.7173.5223.4196.7245.2564.6304.2754.0443.813.7593.6643.5883.3123.5263.3

 ${}^{a}\nu_{1}$  = degrees of freedom in numerator;  $\nu_{2}$  = degrees of freedom in denominator.

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 Table 4: Standard Reduction Potentials of selected half reactions at 25°C

Half-Reaction	<i>E</i> °(V)	Half-Reaction	<i>E</i> °( <b>V</b> )
$\operatorname{Ag}^{+}(aq) + e^{-} \longrightarrow \operatorname{Ag}(s)$	+0.799	$2 H_2O(l) + 2 e^- \longrightarrow H_2(g) + 2 OH^-(aq)$	-0.83
$AgBr(s) + e^- \longrightarrow Ag(s) + Br^-(aq)$	+0.095	$HO_2^{-}(aq) + H_2O(l) + 2e^- \longrightarrow 3OH^{-}(aq)$	+0.88
$\operatorname{AgCl}(s) + e^{-} \longrightarrow \operatorname{Ag}(s) + \operatorname{Cl}^{-}(aq)$	+0.222	$H_0\Omega_0(aa) + 2 H^+(aa) + 2e^- \longrightarrow 2 H_0\Omega(b)$	+1.776
$Ag(CN)_2^{-}(aq) + e^{-} \longrightarrow Ag(s) + 2CN^{-}(aq)$	-0.31	$H_{2}O_{2}(ug) + 2H(ug) + 2C + 2H_{2}O(t)$	+0 789
$Ag_2CrO_4(s) + 2e^- \longrightarrow 2Ag(s) + CrO_4^{2-}(aq)$	+0.446	$1 \text{ Mg}_2^{-1}(a_0) + 2 e^{-1} \rightarrow \text{ Mg}_2^{-1}(a_0)$	+0.920
$AgI(s) + e^{-} \longrightarrow Ag(s) + I^{-}(aq)$	-0.151	$2 \operatorname{Hg}(aq) + 2 \operatorname{e} \longrightarrow \operatorname{Hg}_2(aq)$	10.920
$Ag(S_2O_3)_2^{3-}(aq) + e^- \longrightarrow Ag(s) + 2S_2O_3^{2-}(aq)$	+0.01	$\operatorname{Hg}^{-1}(aq) + 2e \longrightarrow \operatorname{Hg}(l)$ $L_{(s)} + 2e^{-1} \longrightarrow 2L^{-1}(aq)$	+0.854
$Al^{3+}(aq) + 3e^{-} \longrightarrow Al(s)$	-1.66	$1_2(3) + 2e \longrightarrow 21$ (44)	+0.536
$H_2AsO_4(aq) + 2 H^+(aq) + 2 e^- \longrightarrow$	+0.559	$2 IO_3 (aq) + 12 H'(aq) + 10 e \longrightarrow$	+1.195
$H_3AsO_3(aq) + H_2O(l)$		$I_2(s) + 6 H_2O(t)$	-1 015
$Ba^{2+}(aq) + 2e^{-} \longrightarrow Ba(s)$	-2.90	$K^{(aq)} + e \longrightarrow K(s)$	-2.923
$\operatorname{BiO}^+(aq) + 2\operatorname{H}^+(aq) + 3\operatorname{e}^- \longrightarrow \operatorname{Bi}(s) + \operatorname{H}_2O(l)$	+0.32	$L_1'(aq) + e \longrightarrow L_1(s)$	-3.05
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	+1.065	$Mg^{2+}(aq) + 2e \longrightarrow Mg(s)$	-2.37
$2 \operatorname{BrO}_3(aq) + 12 \operatorname{H}^+(aq) + 10 \operatorname{e}^- \longrightarrow$	+1.52	$\operatorname{Mn}^{2+}(aq) + 2 e^{-} \longrightarrow \operatorname{Mn}(s)$	-1.18
$Br_2(l) + 6 H_2O(l)$		$MnO_2(s) + 4 H^+(aq) + 2 e^- \longrightarrow$	+1.23
$2\operatorname{CO}_2(g) + 2\operatorname{H}^+(aq) + 2e^- \longrightarrow \operatorname{H}_2\operatorname{C}_2\operatorname{O}_4(aq)$	-0.49	$Mn^{2}(aq) + 2 H_2O(l)$	
$Ca^{2+}(aq) + 2e^{-} \longrightarrow Ca(s)$	-2.87	$MnO_4^{-}(aq) + 8 H^{+}(aq) + 5 e^{-} \longrightarrow$	+1.51
$\operatorname{Cd}^{2+}(aq) + 2e^{-} \longrightarrow \operatorname{Cd}(s)$	-0.403	$Mn^{2}(aq) + 4 H_2O(l)$	
$Ce^{4+}(aq) + e^{-} \longrightarrow Ce^{3+}(aq)$	+1.61	$MnO_4(aq) + 2H_2O(1) + 3e \longrightarrow$ $MnO_2(2) + 4OVE(22)$	+0.59
$\operatorname{Cl}_2(g) + 2e^- \longrightarrow 2\operatorname{Cl}^-(aq)$	+1.359	$\operatorname{MinO}_2(s) + 4\operatorname{Ori}(uq)$	
$2 \operatorname{HClO}(aq) + 2 \operatorname{H}^+(aq) + 2 e^- \longrightarrow$	+1.63	$HNO_2(aq) + H'(aq) + e \longrightarrow NO(g) + H_2O(l)$ $N(g) + 4 H_2O(l) + 4 e^{-1} \longrightarrow 4 OH^2(aq) + NH(aq)$	+1.00
$\mathrm{Cl}_2(g) + 2 \mathrm{H}_2\mathrm{O}(l)$		$N_2(g) + 4 N_2O(1) + 4e \longrightarrow 4O(1) (uq) + N_2(14(uq))$	-1.16
$ClO^{-}(aq) + H_2O(l) + 2e^{-} \longrightarrow$	+0.89	$N_2(g) + 5 H'(aq) + 4 e \longrightarrow N_2H_5'(aq)$	-0.23
$CI^{-}(aq) + 2 OH^{-}(aq)$		$NO_3(aq) + 4 H'(aq) + 3e \longrightarrow NO(g) + 2 H_2O(l)$	+0.96
$2 \operatorname{ClO}_3^{-}(aq) + 12 \operatorname{H}^+(aq) + 10 e^- \longrightarrow$	+1.47	$Na^{(aq)} + e \longrightarrow Na(s)$	-2./1
$\operatorname{Cl}_2(g) + 6 \operatorname{H}_2\operatorname{O}(l)$		$Ni^{-1}(aq) + 2e \longrightarrow Ni(s)$	
$\operatorname{Co}^{2+}(aq) + 2e^{-} \longrightarrow \operatorname{Co}(s)$	-0.277	$O_2(g) + 4H (aq) + 4e \longrightarrow 2H_2O(t)$ $O_2(g) + 2H_2O(t) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$\operatorname{Co}^{2+}(aq) + e^{-} \longrightarrow \operatorname{Co}^{2+}(aq)$	+1.842	$O_2(q) + 2H_2^+(qq) + 2q^- \longrightarrow HO_2(qq)$	+0.40
$\operatorname{Cr}^{3+}(aq) + 3e^{-} \longrightarrow \operatorname{Cr}(s)$	-0.74	$O_2(q) + 2H^+(aq) + 2e^- \longrightarrow O_2(aq)$	+2.07
$\operatorname{Cr}^{2+}(aq) + e^{-} \longrightarrow \operatorname{Cr}^{2+}(aq)$	-0.41	$O_3(g) + 2H (uq) + 2e \longrightarrow O_2(g) + H_2O(t)$ $Ph^{2+}(aa) + 2e^{-} \longrightarrow Ph(c)$	-0.126
$\operatorname{CrO}_7^{2^-}(aq) + 14 \operatorname{H}^+(aq) + 6 \operatorname{e}^- \longrightarrow$	+1.33	$PbO_{1}(s) + HSO_{1}(ag) + 3 H^{+}(ag) + 2 e^{-} \longrightarrow$	+1.685
$2 \operatorname{Cr}^{-1}(aq) + 7 \operatorname{H}_2 O(l)$	0.12	$PbSO_{4}(s) + 2H_{2}O(l)$	11.005
$Cr(OH)_{*}(s) + 5OH^{-}(ac)$	-0.13	$PbSO_4(s) + H^+(aa) + 2e^- \longrightarrow Pb(s) + HSO_4^-(aa)$	-0.356
$Cu^{2+}(aa) \pm 2a^{-} \longrightarrow Cu(c)$	+0 337	$PtCl_{s}^{2-}(aa) + 2e^{-} \longrightarrow Pt(s) + 4Cl^{-}(aa)$	+0.73
$Cu^{2+}(aq) + ze^{-} \longrightarrow Cu^{+}(aq)$	+0.153	$S(c) + 2 H^+(ac) + 2 a^- \longrightarrow HS(c)$	+0 141
$Cu^{+}(aq) + e^{-} \longrightarrow Cu^{-}(aq)$	+0.133	$U(3) + 2 II (44) + 2 C \rightarrow II_{23}(g)$ $U(3) + 2 II (44) + 4 L^{-} \longrightarrow S(c) + 3 U(0)$	10.45
$Cu(s) + e^{-} \longrightarrow Cu(s) + \Gamma(so)$	-0.195	$\Pi_{2} = \Im_{3} (aq) + 2 \Pi_{1} (aq) + 2 C \longrightarrow \Im_{3} (a) + 3 \Pi_{2} O(l)$	10.40
$F_2(\sigma) + 2e^- \longrightarrow 2F^2(a\alpha)$	-0.185	$n \otimes 4 (aq) + 3 n^2 (aq) + 2e \longrightarrow$	+0.1/
$P_{2}^{2+}(x_{2}) + 2x^{-} \longrightarrow P_{2}(x_{2})$	+ 2.0/	$\operatorname{Sn}^{2+}(aq) + 2e^{-} \longrightarrow \operatorname{Sn}(s)$	-0.136
$\mathbf{Fe}^{-1}(aq) + \mathbf{Ze} \longrightarrow \mathbf{Fe}(s)$	-0.440	$\operatorname{Sn}^{4+}(aq) + 2a^{-} \longrightarrow \operatorname{Sn}^{2+}(aq)$	-0.150
$\operatorname{Fe}^{-1}(aq) + e \longrightarrow \operatorname{Fe}^{-1}(aq)$ $\operatorname{Fe}^{-1}(aq) + e^{-1} \longrightarrow \operatorname{Fe}^{-1}(aq)$	+0.771	$\operatorname{Sn}(uq) + 2e \longrightarrow \operatorname{Sn}^{-1}(4q)$	TU.154
$re(UN)_6$ $(aq) + e \longrightarrow re(UN)_6$ $(aq)$	+0.36	$vO_2^{-1}(aq) + 2H^{-1}(aq) + e \longrightarrow VO^{-1}(aq) + H_2O(l)$	+1.00
$2 H'(aq) + 2 e \longrightarrow H_2(g)$	0.000	$Zn^{-}(aq) + 2e \longrightarrow Zn(s)$	-0.763

## The Periodic Table of Elements

1		-				1		Atomic	number,	z							18
1	Contraction of the second					-		Element	t symbol								2
H 1.008	2	hannan	hann		1.0	800		Relative	atomic r	nass, A <sub>r</sub>		13	14	15	16	17	He 4,00
3 Li 6.94	4 Be 9.01						_					5 B 10.81	6 C 12,01	7 N 14.01	8 0 16,00	9 F 19,00	10 Ne 20,18
11 Na 22,99	12 Mg 24,31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30,97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39,10	20 Ca 40.08	21 Sc 44,96	22 Ti 47,90	23 V 50,94	24 Cr 52,01	25 Mn 54,94	26 Fe 55,85	27 Co 58,93	28 Ni 58,69	29 Cu 63,54	30 Zn 65,41	31 Ga 69,72	32 Ge 72,59	33 As 74,92	34 Se 78,96	35 Br 79,91	36 Kr 83,80
37 Rb 85,47	38 Sr 87.62	39 Y 88,91	40 <b>Zr</b> 91,22	41 Nb 92,91	42 Mo 95,94	43 Tc 98,91	44 Ru 101,07	45 Rh 102,91	46 Pd 106,42	47 Ag 107,87	48 Cd 112,40	49 In 114,82	50 Sn 118,71	51 Sb 121,75	52 Te 127,60	53   126,90	54 Xe 131,30
55 Cs 132,91	56 Ba 137,34	La-Lu	72 Hf 178,49	73 Ta 180,95	74 W 183,85	75 Re 186,21	76 Os 190,23	77 <b>ir</b> 192,22	78 Pt 195,08	79 Au 196,97	80 Hg 200,59	81 TI 204,37	82 Pb 207,19	83 Bi 208,98	84 Po 210	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226.03	Ac-Lr	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [277]	109 Mt [268]	110 Ds [271]	111 <b>Rg</b> [272]	112 Uub [285]						

Lanthanoids	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	<b>Yb</b>	Lu
	138.91	140.12	140.91	144.24	146.92	150.35	151.96	157.25	158.92	162.50	164.93	167.26	168.93	173.04	174.97
Actinoids	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Ac	Th	Pa	U	Np	Pu	Am	Cm	<b>Bk</b>	Cf	Es	Fm	Md	No	Lr
	227.03	232.04	231.04	238.03	237.05	239.05	241.06	244.07	249.08	252.08	252.09	257.10	258.10	259	262

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