DEPARTMENT OF CHEMISTRY UNIVERSITY OF SWAZILAND

C 304

Instrumental Analysis

May 2005 Final Examination

Time Allowed:

Three (3) Hours

Instructions:

- 1. This examination has six (6) questions, one (1) graph sheet, and one data sheet. The total number of pages is seven (7) excluding this page.
- 2. Answer any four (4) questions fully; diagrams should be clear, large and properly labeled. Marks will be deduced for improper units and lack of procedural steps in calculations.
- 3. Each question is worth 25 marks.

Special Requirements:

- 1. Graph Sheet
- 2. Data Sheet

YOU ARE NOT SUPPOSED TO OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GIVEN BY THE CHIEF INVIGILATOR.

Some Useful Physical Constants:

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h = 6.626 \times 10^{-34} \text{ J s}
c = 2.998 \times 10^{8} \text{ m sec}^{-1}
N = 6.02 \times 10^{23} \text{ mol}^{-1}
k = 1.381 \times 10^{-23} \text{ JK}^{-1}
1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}
R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}
Atomic weights: Fe = 55.85; S = 32.06; O = 16.00; H = 1.008; N = 14.01; C = 12.01
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QUESTION 1 [25]

- (a) Hemin, C₂₀ H₂₀ N₄Fe is a oxygen carrying porphyrin component of the haemoglobin molecule. Being highly conjugated, hemin shows distinct absorption bands in the UV-visible portion of the electromagnetic spectrum.
 - i) List the upper and lower limit of the UV-visible region in wavenumbers (cm⁻¹) [1]
 - ii) What type of transition is likely to be taking place when molecules of hemin interact with photons in the subregion mentioned in (i) above? [1]
 - iii) What does the spectroscopic term "bathochromic shift" mean? [1]
- (b) Crystals of hemin were dissolved in concentrated nitric acid and the resultant solution diluted to 100 mL to form a 2 ppm solution. A UV-visible spectrum of the resulting solution as taken, whereby in a 11.7 mm cell, it showed a strong absorption at $\lambda_{max} = 520$ nm of 0.528 absorbance units.
 - i) Sketch the spectrum of this compound [1]
 - ii) What is the transmittance in % of the sample at λ_{max} ? [2]
 - iii) Calculate the molar absorptivity of this compound at $\lambda_{max}[2]$
- (c) The "monochromator" in a spectrometer is a critical component.
 - i) What role does a "monochromator" play in a spectrometer? [1]
 - ii) Describe, using diagrams, the following filters acting as monochromators in a spectrometer:
 - (ii-1) a band pass filter [3]
 - (ii-2) a cut-off filter [3]
- (d) i) Use equations to explain why the source and sample in a spectrometer are kept in a darkened compartment [4]
 - ii) Use equations to explain why measurements in a spectrometer are taken at the "peak" rather than at the "shoulder" [6]

QUESTION 2 [25]

- (a) In the analysis of Fe in natural waters, several reagents are added prior to complexation with 1,10 phenanthroline. Explain the role of the following in this analysis:
 - i) hydroxylamine hydrochloride [1]
 - ii) sodium acetate/acetic acid buffer [1]
 - iii) a blank [1]
- (b) A solution of two isomers, ortho- and para-, are simultaneously determined by uv-visible spectroscopy. At 410 nm, the measured absorbance was 0.353, whereas at 560 nm, the absorbance was 0.251 in a 1.00 cm cell.

- Calculate the concentration of the two isomers (molar absorptivities at 410 nm are: 6000 for ortho-, 500 for para-; at 560 nm they are 2152 for ortho-, 5260 for para-) [5]
- (c) Use diagrams to explain how the "Molar Ratio Method" can be used to determine stoichiometry [3]
- (d) Draw the expected Job's plot for a complex M_nL_x where n=x=1 at low ligand concentration, and n=1,x=3 at high ligand concentration [3]
- (e) Two elements, X and Y, are to be analyzed by flame AA and flame emission. The transition for element X is designated ${}^2S_{1/2} \longrightarrow {}^2P_{3/2}$ and has a wavelength of 852.1 nm. For Y it is ${}^1S_o \longrightarrow {}^1S_1$ and has a wavelength of 228 nm. What is the ratio of excited to ground state atoms if the flame is operated at 2250 °C for each element? [6]
- (f) Use the ratios obtained in (d) above to decide which element is best analyzed by which method. State a reason for your choice in each case [2]
- (g) Name three elements that are determined by flame photometry in clinical analysis [3]

OUESTION 3 [25]

- (a) The most widely used region in the electromagnetic spectrum for organic functional group identification is the infra-red (IR) region.
 - i) What are the borders of IR in electron volts? [2]
 - ii) Using the CO₂ molecule as an example, describe two (2) common modes of molecular vibrations that give rise to IR radiation [2]
- (b) In dispersive IR, double beam instruments are used, whereby two beams pass through the sampling area before reaching the monochromator and detector.
 - i) Explain why the beam is split into two before reaching the sampling area [2]
 - ii) Explain why the beams pass through the sampling area before reaching the monochromator and not after it [2]
 - iii) Explain why the exact opposite of the arrangement in (ii) above is done in UV-visible instrumentation [2]
- (c) Analytical instruments configured in the Czerny-Turner arrangement of optical components use a "grating" as a monochromator.
 - i) In physical appearance, what does the grating look like? [1]
 - ii) State the Bragg equation for the grating, and explain all the terms that appear in it [3]
 - iii) If the grating is 5 cm wide with 11, 800 lines/mm, calculate its first order resolving power [3]
- (d) Although it is primarily a functional group identification tool, IR spectroscopy may sometimes be successfully used for quantitative analysis of organic compounds. One such case is the quantitative analysis of Thio-Mickler's Ketone (TMK), where the carbonyl functional group of TMK appearing at 1785 cm⁻¹ is used. Supposing a 5.2031-g tablet containing TMK is dissolved in 100 mL, and that this solution, together with TMK standards, yielded the following results:

Sample	I	Io	Absorbance			
0 ppm standard	A	5638	0.000			
2 ppm standard	4351	В	0.103			
4 ppm standard	3526	5641	С			
Unknown	4025	5636				

- i) Calculate A [1]
- ii) Calculate B [1]
- iii) Calculate C [1]
- iv) Draw the calibration curve of TMK [2]
- v) What was the concentration (in μg/g) of TMK in the unknown sample [3]

QUESTION 4 [25]

- (a) Analytical chemists agree that the technique of atomic absorption "came of age" with the invention of the hollow cathode lamp by Sir Walsh in 1955.
 - i) Draw and label the hollow cathode lamp [2]
 - ii) Explain how the hollow cathode lamp works [2]
- (b) There are procedures commonly employed by analysts when using a flame atomic absorption spectrophotometer. Explain
 - i) Why in the analysis of Ca in soils, EDTA is added to all solutions [1]
 - ii) Why in the analysis of Sr in foodstuffs, 1000 ppm La is added to all solutions [1]
 - iii) Why in the analysis of Cu in a plant sample, the instrument is operated under "standard additions" mode
- (c) A major breakthrough in atomic absorption spectrophotometry since the invention of the hollow cathode lamp is graphite furnace AA.
 - i) What is the major structural difference between flame AA and graphite furnace AA? [2]
 - ii) Identify the physical stages involved in a furnace program, and describe the processes that occur during each stage [3]
 - iii) Describe two (2) advantages of graphite furnace AA over flame AA [2]
- (d) In 2001, the Swaziland Water Services Corporation acquired a new atomic spectrometer called the Liberty 110 ICP.
 - i) What does the acronym ICP stand for? [1]
 - ii) Explain how a "doughnut" shaped ICP is formed, and why it is preferred over a "tear-drop" shaped ICP.
 [3]
 - iii) What are the normal operating values of the ICP in terms of:

 Power in KW------[1] Temperature in K-----[1]
 - iv) In the ICP, direct reading of several lines at once is possible. With the aid of a diagram, explain how this is possible [3]
 - v) List two (2) advantages of ICP compared to FAAS or GFAAS [2]

QUESTION 5 [25]

Gas Chromatographic techniques have many applications in analytical chemistry, especially in the area of pesticide and drug analysis.

- (a) In GC, explain what is meant by
 - i) Temperature programming [1]
 - ii) the "race-track" effect [1]
- (b) The power of separation, technically the "resolution" in GC, depends on the plate number, or alternatively the HETP, which has its theoretical origins embodied by the Van Deempter principle. With regards to HETP for a GC packed column,
 - i) explain the origin of "Eddy Diffusion"[1]
 - ii) write down the equation that relates HETP to Eddy Diffusion, and explain all terms that appear in it [2]
 - iii) explain the origin of "Longitudinal Diffusion"[1]
 - iv) write down the equation that relates HETP to Longitudinal Diffusion, and explain all terms that appear in it [2]
- (c) Draw the Van Deempter Plot for packed column GC, and identify the point in the plot that is used to determine the optimum velocity of carrier gas [3]
- (d) A GC instrument equipped with a 3-m steel column packed with Chromosorb W-AW on PEGS stationery phase and a Flame Ionization Detector, was used to quantify two alcohols, methanol and ethanol. 2-butanol was used as an internal standard. In the chromatogram, an unretained air peak appeared at 30 sec, while peaks for the two alcohols of interest appeared at 3 and 3.5 min respectively.
 - i) What is meant by the prefix "AW" in Chomosorb W-AW? [1]
 - ii) State the order in which the three alcohols will elute out of the analytical column [1]
 - iii) Describe the role of 100%v/v 2-butanol in the analysis [1]
 - iv) Draw and label a diagram of an FID, and explain how it works [4]
 - v) Calculate the capacity factor of ethanol [2]
 - vi) If the column had 320 theoretical plates, what is the width of the methanol peak? [2]
 - vii) Are these two peaks properly resolved? Explain why or why not [3]

QUESTION 6 [25]

Liquid Chromatographic techniques have many applications in analytical chemistry, especially in the area of food and drug analysis.

- (a) In LC, explain what is meant by
 - i) Solvent programming [1]
 - ii) Isocratic elution [1]

- (b) The power of separation, technically the "resolution" in LC, depends on the plate number, or alternatively the HETP, which has its theoretical origins embodied by the Van Deempter principle. With regards to HETP for an LC packed column,
 - i) explain the origins of "Resistance to Mass Transfer in the Stationary Phase"[2]
 - ii) write down the equation that relates HETP to Resistance to Mass Transfer in the Stationary Phase, and explain all terms that appear in it [3]
 - iii) explain the origin of "Resistance to Mass Transfer in the Stagnent Mobile Phase"[2]
 - iv) write down the equation that relates HETP to "Resistance to Mass Transfer in the Stagnent Mobile Phase", and explain all terms that appear in it [3]
- (c) Draw the Van Deempter Plot for packed column LC, and identify areas in the plot which are different from those of gas chromatography [3]
- (d) HPLC is widely used for Vitamin A analyses. In a typical analysis, after pre-treatment and priming, both sample and standards are injected into an HPLC instrument fitted with a 20-cm 0.5-in. glass column in a reverse-phase bonded phase mode. Eluents are detected by means of a uv detector at 254 nm.
 - i) What does the acronym "HPLC" stand for? [1]
 - ii) Describe the process of "priming"in HPLC [1]
 - iii) What is the reason for the use of bonded phases in HPLC? [1]
 - iv) Use chemical equations to describe how bonded phases are synthesized in the laboratory [3]
- (e) In a lot of instances, column materials are "silinized" in chromatography.
 - i) What is the role of "silinization" in chromatography [1]
 - ii) Use chemical equations to describe how silinization is achieved in the laboratory [3]

```
inecator pH range pKin Ac
                                                                                                                                                 D.F. t<sub>50</sub>
1 1.0
                                                                                                                               n Q<sub>90</sub>
                                                                                                                                                                6.3 13
                                pH range pKin Acid
                                                                                                           n Q<sub>90</sub>
6 0.56
                                                                        Base
                                                                                            Q00
                                                                                                                                                                                64
                                                                                                                                9
                                                       red
                                                                        yellow
                                                                                                                                   0.44
 Thymol blue
                                1.2 - 2.8
                                                1.6
                                                                                            0.94
                                                                                                                                                    2
                                                                                                                                                                                 9.
                                                                                                                                                        0.82
                                                                                                                                                                2.9
                                                                        yellow
                                 2.9 - 4.0
                                                       red
                                                                                            0.76
                                                                                                           7
                                                                                                                0.51
                                                                                                                              10
                                                                                                                                    0.41
                                                3.3
 Methyl yellow
                                                                                                                                                    3
                                                                                                                                                         0.76
                                                                                                                                                                 2.35
                                                                                                                                                                                 5.
                                3.1 - 4.4
3.8 - 5.4
                                                 4.2
                                                       red
                                                                        yellow
                                                                                            0.64
                                                                                                           8
                                                                                                                0.47
 Methyl orange
                                                                                                                                                        0.74
                                                                                                                                                                2.13
                                                                        blue
                                                       yellow
                                                 4.7
 Bromocresol green
                                                                                                                                                                 2.02
                                                                                                                                                                         2.57
                                                                                                                                                         0.73
                                                                                                15. Bond Enthalpies
                                                                        yellow
                                 4.2 - 6.2
                                                       red
                                                 5.0
 Methyl red
                                                                                                                                                        0.72
                                                                                                                                                                 1.94
                                                                                         kJ mol-1 at 25°C (i.e. Bond Energies)
Single O N C S F C
                                                       yellow
                                 4.8 - 6.4
                                                                        red
 Chlorophenol red ·
                                                 6.0
                                                                                                                                                                1.90
                                                                                                                                                                         2.36
                                                                                                                                     CI
                                                                                                                                                         0.71
                                                                                        Single
                                                        yellow
                                                                                                463 391 413 368
                                 6.0 - 7.6
                                                 7.1
                                                                        blue
                                                                                                                            563
                                                                                                                                   432
 Bromothymol blue
                                                                                                                                                    8
                                                                                                                                                         0.71
                                                                                                                                                                 1.86
                                                                                                                                                                         2.31
                                                                                         H
                                                        yellow
                                                                                                358 305 346 272
222 163 MISC.
                                 6.4 - 8.0
                                                                        red
                                                                                                                             489 328
                                                                                                                                                         0.70
 Phenol red
                                                                                         C
                                                                                                                                                                 1.83
                                 7.4 - 9.0
                                                        yellow
                                                 8.3
                                                                        purple
                                                                                                                                                         0.70
                                                                                                                                                                         2.23
                                                                                                                                                   10
                                                                                                                                                                 1.81
 Cresol purple
                                                                                                                                    192
                                                                                              -S 251 H—H 436
-F 327 N≡N 946
                                                                                                                                                                         2.09
                                                                                                                                                                                 2
 Thymol blue
                                 8.0 - 9.6
                                                 8.9
                                                        yellow
                                                                        blue
                                                                                                                            C=C 615
                                                                                                                                                   20
                                                                                                                                                         0.69
                                                                                                                                                                 1.72
                                                                                                                            C=C 812
                                 8.0 - 9.8
                                                 9.7
                                                        colorless
                                                                        red
                                                                                                                                                   30
                                                                                                                                                         0.68
                                                                                                                                                                 1.70
                                                                                                                                                                         2.04
 Phenolphthalein
                                                                                                                                                         0.67
                                                                                                                                                                 1.64
                                                                                                                                                                         1.96
                                                        colorless
                                                                        blue
                                9.3 - 10.5
                                                 9.9
                                                                                                                                                   8
 Thymolphthalein
                                                                                               C1 271 N=O 607
                                                                                                                            C=0 749
                                                                              16. HEATS OF FORMATION
                                                                                                                                        20. CONC. ACIDS AND BAS
      12. ELECTRODE POTENTIALS, &°
                                                                               All ions in H<sub>2</sub>O solution except as noted
                                                        -2.713
 Na· + e ≠ Na
                                    SKA .
                                                                                                                                                     M.W. Density Wt. %
                                                        - 2.37
                                                                                        All Elements = 0
 Mg^{++} + 2e \iff Mg
                                                                                                                                                      60.05 1.05
                                                                                                                                                                        99.5
                                                                                                                                                                                  1
                                                                                                                                          Acetic
                                                                                                          0.0 H<sub>2</sub>O<sub>9</sub> -
                                                                                                                             -242
 Al^{***} + 3e \Leftrightarrow Al
                                                        -1.66
                                                                        H,
                                                                                            H+
                                                                                     218
                                                                                                                                         H<sub>2</sub>SO<sub>4</sub>
HF
                                                                                                                                                      98.07
                                                                                                                                                                1.83
                                                                                                         240 H<sub>2</sub>O<sub>1</sub> -
                                                                                                                             -286
                                                        -0.763
 Zn^{**} + 2e \rightleftharpoons Zn
                                                                         O,
                                                                                             Na+
                                                                                     249
                                                                                                                                                      20.01
                                                                                                                                                                                  2.
                                                                                                                                                                1.14
                                                                                                                                                                         45
                                                                        Č,
                                                                                                                CO,
                                                                                                                              -111
                                                                                                         106
 Fe" + 2e == Fe
                                                        -0.44
                                                                                     717
                                                                                             Agt
                                                                                                                                         HCl
                                                                                                                                                      36.46
                                                                                                                                                                1.19
                                                                                                                                                                         38
                                                                                                                 CO<sub>2</sub>
                                                                                             NH.
                                                                                                                             -394
                                                                                     473
                                                                                                      ---133
                                                        -0.403
 Cd·· + 2e ≒ Cd
                                                                                                                                                      80.91
                                                                                                                                                                1.52
                                                                                                                                                                         48
                                                                                                                                         HBr
                                                                                                         _230
                                                                                                                NH_{3g}
                                                                        F,
C1,
                                                                                                                             --46
 Cr*** + e ≒ Cr**
                                                                                      79
                                                                                             OH-
                                                        -0.38
                                                                                                                                         HNO_3
                                                                                                                                                      63.01
                                                                                                                                                                1.41
                                                                                                                                                                         69
                                                                                                                 NO,
                                                                                                                                90
                                                                                             F−
                                                                                                      ---333
                                                        -0.336
                                                                                     122
 Tl^+ + e \rightleftharpoons Tl
                                                                                                                                         HClO<sub>4</sub> 100.46
                                                                                                                                                                1.67
                                                                                                                                                                         70
                                                                                                                 NO<sub>2</sub>
                                                                        \mathbf{Br}_{g}
                                                                                     112
                                                                                             C1-
                                                                                                      ---167
                                                                                                                                33
 V··· + e ⇌ V··
                                                        -0.255
                                                                                                                                         H<sub>3</sub>PO<sub>4</sub>
                                                                                                                                                      98.00
                                                                                                                                                                1.69
                                                                                                                                                                         85
                                                                                                                                 9
                                                                                     107
                                                                                             Br
                                                                                                      -122
                                                                                                                 N2O46
 Sn + 2e = Sn
                                                        -0.14
                                                                                                                                         NaOH
                                                                                                                                                      40.00
                                                                                                                                                                 1.53
                                                                                                                                                                          50
                                                                                                                SO<sub>2</sub>g -
                                                                                                                               297
                                                                        S_{g}
                                                                                     279
                                                                                             T-
                                                                                                        —55
                                                                                                                                         NH<sub>3</sub>
                                                                                                                                                      17.03
                                                                                                                                                                 0.90
                                                                                                                                                                         28
                                                         -0.126
 Pb++ + 2e + Pb
                                                                                                                 SO3,
                                                                                                                               396
                                                                         \mathbf{P}_{g}
                                                                                     315
                                                                                             S=
                                                                                                           33
 2H^{\bullet} + 2e \rightleftharpoons H_2
                                                            0.000
                                                                        Na
                                                                                             SO<sub>4</sub>= --909
                                                                                                                 H_2S_g
                                                                                                                            --21
                                                                                                                                             21. DENSITIES (g cm-3)
                                                                                     107
 S_+O_0 + 2e \rightleftharpoons 2S_2O_3 =
TiO" + 2H' + e \rightleftharpoons Ti" + H_2O
                                                            0.09
                                                                                             CO_3 = -677
                                                                                                                               -574
                                                                         K,
                                                                                      88
                                                                                                                 NaF.
                                                                                                                                                          Air (70 cm)
                                                                                                                                                                               0.00
                                                                                                                                         Water at
                                                            0.10
                                                                                             \mathbf{HF}_{g}
                                                                                                                 NaCl.-
                                                                                                                              411
                                                                                     609
                                                                                                     --271
                                                                         Na⁺,
                                                                                                                                       0,°C 0.9168
                                                                                                                                                          Glass
                                                                                                                                                                                2.7
 S + 2H^{+} + 2e \Leftrightarrow H_{2}S
                                                            0.14
                                                                                                                 KF,
                                                                                                                               -567
                                                                         K^+_g
                                                                                     514
                                                                                             HC1
                                                                                                        --92
                                                                                                                                                          Na<sub>2</sub>CO<sub>3</sub>
                                                                                                                                       10°
                                                                                                                                               0.9997
                                                                                                                                                                                2.5
                                                            0.14
0.17
 Sn^{+4} + 2e \leftrightharpoons Sn^{-+}
                                                                                             HBrg
                                                                                                                 KCL. -
                                                                                                                                       20°
                                                                        F-g
                                                                                     -255
                                                                                                           -36
                                                                                                                               437
                                                                                                                                                           NaCl
                                                                                                                                                                                2.2
                                                                                                                                               0.9982
 Cu++ + e = Cu+
                                                                                                                 AgC1.-127
                                                                                     -233
                                                                                                                                       22°
                                                                         C1-,
                                                                                             HI_g
                                                                                                           26
                                                                                                                                               0.9978
                                                                                                                                                           BaSO<sub>4</sub>
                                                                                                                                                                                4.5
                                                            0.17
 SO_1 = +4H^2 + 2e + H_2O + H_2SO_3
                                                                                             HČN,
                                                                                                                AgBr. —100
PC1<sub>89</sub> —287
                                                                         CH49
                                                                                   —75
                                                                                                                                                           AgCl
                                                                                                          135
                                                                                                                                       24°
                                                                                                                                               0.9973
                                                                                                                                                                                5.6
 AgCl + e \rightleftharpoons Cl - + Ag
                                                            0.222
                                                                                     227
                                                                                             PH3g
                                                                                                                                       26°
                                                                                                                                                                                2.7
                                                                         C_2H_2
                                                                                                                                               0.9968
                                                                                                                                                           Aluminum
                                                          (0.244)
 Saturated calomel
                                                                                                            49 PC15,-
                                                                         C_2H_4
                                                                                      52
                                                                                             CoHe:
                                                                                                                               -375
                                                                                                                                       28°
                                                                                                                                               0.9963
                                                                                                                                                           Iron
                                                                                                                                                                                7.9
 Hg_2Cl_2 + 2e \Leftrightarrow 2Cl - + 2Hg \sim
Bi··· + 3e \Leftrightarrow Bi
                                                            0.268
                                                                                                            CH3OH1 -
                                                                                 C<sub>2</sub>H<sub>6</sub>,
C<sub>3</sub>H<sub>8</sub>,
nC<sub>4</sub>H<sub>10</sub>,
                                                                                                                               238
                                                                                                                                       30°
                                                                                                                                                           Brass
                                                                                                                                               0.9956
                                                                                                                                                                                8.4
                                                                                                 ---85
                                                            0.293
                                                                                                                                       90°
                                                                                                            C2H5OH,
                                                                                                                               -235
                                                                                                                                                                              13.6
                                                                                                                                               0.9653
                                                                                                                                                           Mercury
  UO_2 · · · · · 4H· · + 2e \rightleftharpoons U · · · + 2H<sub>2</sub>O

VO · · · + 2H· · + e \leftrightharpoons V · · · · + H<sub>2</sub>O
                                                                                                ---105
                                                            0.33
                                                                                                            C<sub>2</sub>H<sub>5</sub>OH<sub>1</sub> —278
COC1<sub>2</sub>" —219
                                                                                                                                       100,° 0.0006
                                                                                                                                                           Platinum
                                                                                                                                                                              21.4
                                                                                               --127
                                                            0.34
                                                                                 nC_8H_{180} —209
                                                            0.34
  Cu** + 2e = Cu
                                                                                                                                       22. MOBILITIES (m^2V^{-1}s^{-1} \times 1
                                                                                               ---135
                                                                                 CC141
                                                                                                            CH<sub>8</sub>C1,
                                                                                                                             —81
                                                            0.355
  Fe(CN)_6^{-3} + e \rightleftharpoons Fe(CN)_6^{-4}
                                                                                                                                       Li+
                                                                                                                                                 39
                                                                                                                                                       H_3O
                                                                                                                                                                  350
                                                                                                                                                                          ∄Ba++
                                                            0.52
  Cu' + e + Cu
                                                                                    17. ABS. ENTROPY S°
                                                                                                                                                                   73
                                                                                                                                                                          1 La+3
                                                                                                                                                       NH4+
                                                                                         J mol-1 K-1, at 25°C
P<sub>4 wh</sub> 164 SF<sub>6</sub>,
                                                                                                                                        Na+
                                                                                                                                                 50
  I<sub>3</sub>-+ 2e ₹ 3I-
                                                            0.545
                                                                                                                                                 74
                                                                                                                                                                   62
                                                                                                                                                                         350,=
                                                                                                                                       K+
                                                                                                                                                       Ag
                                                            0.56
  H_3AsO_4 + 2H^4 + 2e \rightleftharpoons H_3AsO_3 + H_2O
                                                                         H_{2g}
                                                                                            Pawa
                                                                                    131
                                                                                                                           292
                                                                                                                                                76
                                                                                                                                                       OH-
                                                                                                                                                                         3PO4-8
                                                                                                                                                                  198
                                                                                                                                       C1r
                                                            0.621
                                                                                            \mathbf{HF}_{g}
                                                                                                                NO,
  I_2 + 2e \rightleftharpoons 2I^-
                                                                                                                           211
                                                                                    192
                                                                                                       174
                                                                         N_{2g}
                                                                                                                                                                         NO<sub>3</sub>
                                                                                                                                        Br
                                                                                                                                                 78
                                                                                                                                                       Ι-
                                                                                                                                                                   77
  2 \text{HgCl}_2 + 2 \text{e} \rightleftharpoons \text{Hg}_2 \text{Cl}_2 + 2 \text{Cl} - \checkmark
                                                             0.63
                                                                         O<sub>2</sub>,
Cl<sub>2</sub>,
                                                                                    205
                                                                                            HC1,
                                                                                                       187
                                                                                                                NO_{2g}
                                                                                                                            240
                                                                                                                N_2O_{4g}
  O_2 + 2H^2 + 2e \rightleftharpoons H_2O_2
                                                             0.69
                                                                                   223
                                                                                            H_2O_y
                                                                                                                           304
                                                                                                                                            23. WATER V.P. (torr)
                                                                                                       189
  Quinone + 2H* + 2e ≠ Hydroquinone
                                                            0.70
                                                                                    203
                                                                                                       198
                                                                                                                           192
                                                                         \mathbf{F}_{2g}
                                                                                             CO,
                                                                                                                NH_{3}
                                                                                                                                                                         25°
                                                                                                                                          0°C
                                                                                                                                                       4.6
                                                                                             CO<sub>2</sub>
                                                                                                                PC13,
  Fe'" + e ⇌ Fe'
                                                             0.771
                                                                          Cgra
                                                                                    5.7
                                                                                                                           312
                                                                                                       214
                                                                                                                                         15°
                                                                                                                                                      12.8
                                                                                                                                                                         30°
  Hg; " + 2e ≠ 2Hg
                                                                         S<sub>8</sub>, 256
CH<sub>4</sub>, 186
C<sub>2</sub>H<sub>6</sub>,
                                                                                                                PC1<sub>50</sub>
                                                                                    254
                                                             0.792
                                                                                                                            365
                                                                                                                                         20°
                                                                                                                                                                         50°
                                                                                             SO_{2g}
                                                                                                       248
                                                                                                                                                      17.5
   Ag+ + e = Ag
                                                                                                                BF3,
                                                                                             SO<sub>3</sub>,
                                                                                                                           254
                                                             0.799
                                                                                                       256
   Hg++ + 2e = Hg
                                                             0.851
                                                                                                       CH<sub>3</sub>OH<sub>1</sub>
                                                                                                                            127
                                                                                                                                                24. MISCELLANEOUS
   2Hg^{**} + 2e \Longrightarrow Hg_2^{**}
                                                             0.907
                                                                                C<sub>3</sub>H<sub>8</sub>,
                                                                                              270
                                                                                                       C2H5OH,
                                                                                                                            283
                                                                                                                                         Std. dev. = \sqrt{2} (X_1 - \overline{X})^2/(n-1)

Conf. limits = \overline{X} \pm ts / \sqrt{n}

E=E<sup>3</sup> - (0.0592/n)log([Red]/[Ox])

log I<sub>s</sub>, I<sub>1</sub> = abc = A = log 1/T

log N<sub>T</sub> = logN<sub>0</sub> - 0.301T/T<sub>1</sub>

x = (-b \pm \sqrt{b^2 - 4ac})/2a

n\ = 2d sin 0
   N\ddot{O}_3 + 3H + 2e \Rightarrow HNO<sub>2</sub> + H<sub>2</sub>O
                                                                                                       C<sub>2</sub>H<sub>5</sub>OH<sub>1</sub>
(CH<sub>3</sub>)<sub>2</sub>O,
CH<sub>3</sub>COOH,
                                                             0.94
                                                                                              201
                                                                                                                           161
                                                                                C_2H_{2\sigma}
  HNO_2 + H^2 + e \leftrightharpoons NO + H_2O

VO_2 + 2H^2 + e \leftrightharpoons VO^2 + H_2O
                                                             0.98
                                                                                C_2H_4,
                                                                                              219
                                                                                                                            266
                                                                                C<sub>6</sub>H<sub>6,9</sub>
                                                                                              269
                                                                                                                           282
                                                             0.999
   Br_0 + 2e \leftrightharpoons 2Br
                                                             1.08
                                                                                    18. △G° FORMATION
   2IO_3 - + 12H' + 10e \iff 6H_2O + I_2
                                                             1.19
0_{1}^{2} + 12H + 10e = 0H_{2}O + 12H_{2}O

0_{1}^{2} + 4H^{2} + 4e = 2H_{2}O

0_{1}^{2} + 4H^{2} + 2e = Mn^{2} + 2H_{2}O

0_{1}^{2} + 14H^{2} + 6e = 7H_{2}O + 2Cr^{2}
                                                                                           kJ mol-1 at 25°C
                                                                                                                                          2.303 \log_{10} a = \log_{\bullet} a

h = 6.626 \times 10^{-34} \text{ J s}

e = 1.602 \times 10^{-19} \text{ C}

N_{A} = 6.022 \times 10^{23} \text{ mol}^{-1}

F = 96.97 \text{ C}
                                                             1.229
                                                                                             HF, —273 H<sub>2</sub>O,
HC1, —95 H<sub>2</sub>O<sub>1</sub>
                                                                          H,
                                                              1.23
                                                                                    203
                                                                                                                               -229
                                                                          F,
C1,
                                                                                                                               -237
                                                             1.33
                                                                                      62
                                                                                                        -54 SO<sub>29</sub>
                                                             1.358
                                                                                     106
                                                                                             HBr_g
                                                                                                                               -300
   Cl_2 + 2e \Leftrightarrow 2Cl^-
                                                                                                           1.7 SO3,
                                                             1.50
                                                                          O_{\sigma}
                                                                                     232
                                                                                             HI_g
                                                                                                                               -371
   2BrO_{3}^{-} + 12H' + 10e \iff 6H_{2}O + Br_{2}
                                                                                                                                          g = 9.807 \text{ m s}^{-2}
                                                                          NO,
                                                                                                        -16 PCI<sub>3,0</sub>
                                                                                             NH_{39}
                                                                                                                               -268
   MnO_4^- + 8H^+ + 5e \Leftrightarrow 4H_2O + Mn^{++}
                                                              1.51
                                                                                      87
                                                                                                                                          c = 2.998 \times 10^8 \text{ m s}^{-1}
                                                                          NO<sub>2</sub>,
                                                                                                       _137 PC159
                                                                                              COg
                                                                                                                               -305
   Ce+4 + e = Ce+3
                                                              1.61
                                                                                      51
                                                                                                                                          l \text{ amu} = 1.661 \times 10^{-27} \text{ kg}
                                                                                              CO2g
                                                                                                           394 CH40
                                                                          N<sub>2</sub>O<sub>4</sub>, 98
                                                                                                                             --51
                                                                                                                                          R = 1.987 cals mol-1 K-1
    13. MEAN ACTIVITY COEFFICIENTS
                                                                          C2H4, 68.
                                                                                                                             -33
                                                                                              C_2H_{2g}
                                                                                                           209 C2H69
                                                                                                                                             == 0.08206 litre atm mol-1 K-1
                                                    ZnSO_4
                                 Na_2SO_4
           M
                        KCl
                                                                                                                               -162
                                                                                                                                             = 8.314 Lmol-1 K-1
                                                                                                         CH<sub>3</sub>OH<sub>1</sub>
                                                                            C6H61
                                                                                                125
                                                                                                                                              == 8.314 kPa dm3 mol-1 K-1
          0.001
                         0.965
                                        0.89
                                                      -0.70
                                                                                                                            ---175
                                                                            CČ141
                                                                                               —65
                                                                                                         C2H5OH1
                                                                                                                                           O °C == 273.15 K
          0.01
                         0.901
                                        0.72
                                                       0.39
                                                                                                         CHC13,
                                                                                                                              ---70
                                                                                            -1120
                                                                            BF3,
                                                                                                                                          1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}

1 \text{ cal} = 4.1840 \text{ J}
          0.1
                         0.769
                                                       0.15
                                                                                                                               -374
                                                                                                         CH3COOH, -
                                                                                              -1105
```

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VACC 1 - girling

			. ;	3522	1.	PER	IODI	C CH	ART	of 1	HE	ELE	MEN	ITS	, .	E (*)		_18	١.,	ATEMS CON	
Ÿ	, 1	2											13	14	15	16	. 17	2		NET STA	
	1A	2A						1.00					3A		5A				Ag($CN)_2$	5×10
	3	4											3	6	7	8	9	10	Ag(NH ₃) ₂ +	1.6×10
		Вe											B	C	N					S ₂ 0 ₃) ₂ -3 OH) ₄ -	
	11	12	. •										13	12.013	14.004	15.9994	10,55			EDTA)=	1.0×10
	Na	Mg	3	· 4	5	6	7	8	9	10	11	12	A	Si	P		Č		Cal	$CN)_4 =$	8.3×10
	22,98977	24.305	38	48	-58	68	78		- 88		18	2B	26.981	28.085	30,973	76 J2.04	35.4	53 39,948	Cd()	$NH_3)_4$	5.5×10
	K	20 Ca	5°c	22 Ti	V 23	Cr	Mn Mn	Fe	Co	Ni Ni	Ĉu	Zn	Ge C	32 Ge] 33 A				Co(VH ₃) ₆ +3	2×10
	39.09E3	40.04	44.9559	47,85	50.9415	51.994	54.9360			58.69	43.546	65.38	69.72						Cr	OH) ₄ -3	4×10
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53		Cuc	NH ₈) ₄ ++	1 × 10
	Rb	5r	¥4.7057	Zr	Nb	Mo	TC:		Rh	Pd	A9	Cd	114.6						Fe({	CN) ₆ -3	4.0 × 10
	55	.56		72	73	74	75		77	78	79	80	81	82	83	_	124.9	_	Fe((CN) ₆ -4	2.5×10
	Cs	Ba	La	Hf	Ta	W	Re	Os.	r		Αu	Hg	TI	Pb	Bi	Po	·ΙΑ	t Rn	HgC	CN)+	1.0 × 1(
	132,9055 87	117.23	13k,9055	178.49	105	106	186,207	190.2	102	195.08	94.9665	200.59	764.38	3 207.1		04 (209)	. (210	R 2222	Hg	$CN)_4 =$	1.3×10
	Fr	Ra			1 '			1.	Une					tes the			rof		Hg(SCN) =	5.0×10^{-1}
	(323)	224.0354	27.0278	Ung (25:1)	Unp	Unh	Uns (mex)		(592)	the lor	igest i	lived o	r best	known	isotop	e.			HgI	·=	6.3×10^{-1}
				18	59 (50 6	51 6	2 6	3 64	6		66 6	57 T	68	69	70	71		Mg(EDTA)=	1.3×1(
		enthanic Pries	* C	e l	Pr N	Id P		m E			6 D	y	loi	Er 1	ľm `	Yb	Lu		Ph	(H ₃)₄ ⁺⁺ OH)₃⁻	7.9×10
			_		_	92 9	_	0.36 151. 4 95	_	_			_		_		174.900 T	•	Zn($CN)_4=$	4.2 × 1(
		ctinide eries		_				υA							101 //d /		103 Lr		Zn(VH _R) _A ↔	7.8×10^{-1}
	-					£0289 237											(240)		Zn (OH) =	6.3×10^{-1}
		ION	TZAT	TON	CON	STAI	TS (K _A) F	OR V	VEAF	C AC	IDS			5. F	RST	ION	IZATIO	ON EN	ERGIES	ev.
	Acetic				\times 1		1	Hypoc				\times 1									, 4
	2-Ami				-			H_2S			. 9	\times 1	0 -8	1A 5.4				14			5A 4A 7A
		idiniu			\times 1	0-7 0-10	1	Imida	muilos		· 1 11	X 1				41 51	L 6È	78	· 15 ;		11 10 13
	Amme Anilin				$\times 1$		1	Lactic				χī								24 6.0 8.1	
	Arsen		K	, 5.6	Ωî	0-3		Methy	rlamm	oniun			0-11	7.3		7.0 6.1				10 5.5 7.3	
la Law	Benzo			6.7	$\times 1$	0-5		Ion Monos	thano	1-	2.1	\times 1	.0	3.5	12 50 69	5.5 6	TO:	79 47 92	20 92	10 41 74	8
	Boric Carbo			1 5	X 1 X 1	0-10 N-7	ĺ		noniur			× 1	() -10		6. E	LEC	rro	NEGAT	IVITIE	S, Pauli	ng
	Carbo	anc.	K	2 5.6	Ŷ î	0-11	1	Nicoti		_		\times 1	0-0							,	
	Chlore		2	1.5	\times 1	0–s		Oxalio	:		. 6 . 6	X 1 X 1	ე–5 	1A				2.1			5A 6A 7A 3.0 3.3 4.0
	Chron Citric			2 3.2 1 8.7	$\times 1$	()—7 ()—4		Pheno	1		1.3	\times 1	0-10			48 SE		71	18 ;		2.1 2.5 3.0
	Ozuric		K	. 1.8		0-5 0-5		Phtha	-	K.	2 4 _	X 1	0-e					13 18 18			24 24
	D: 11		K	8 4	\times 1	0 -e		Phosp	noric	K	, 62	X 1 X 1	0–8 0–8							7 1.7 1.8	
	Dichlo EDTA	oroace	tic K	. 5 . 7	$\times 1$	}~2 ∩-2						·x i		0.7	0.9 1.7	1.3 1.5	ינו	1.9 2.2 2.2	2.2 2.4	.9 1.8 1.8 1	9 2.0 2.2
		•	K	, 2	\times 10	D—3		Phosp	horou	s K	1.0	\times 1	0-2			- A	móa	MTC DA	DIT . '		
			ĸ	₃ 7	\times 1	D-7		Pyridi	nium	Ion	2 2.6 1	$\times 1$				7. E	TOI		DIT DIG	ometers	_
	Formi		K	, 6 2	X 1)–11 ∩–4	i	Succi	ic.	K	17	\times 1	0-5	1A 2	_			37		3A 4A 5A	
	α-D(-		ucose		$\hat{\mathbf{x}}$)-13		C1£	<u>.</u>	K	<u>.</u> 2.5	XI	()-6 ()-7	155 11	_	4B 5B I	8B 78	_88 <u></u>	18 28	98 81 92 143 132 121	
	Glycir	ium I	on K	1 4.6	\times 10)-3	ì	Sulfur Sulfur			2 1.4 2	X 1 X 1	0-2	235 19	97 152	47 134	130 135	126 125 1	14 128 138	141 137 131	140 114
1	Hydra	zini	K n Tor	. 2.5	$\times 10^{-1}$	D–5 D–10		_			6	χī	8-0.	248 2	15 178 1	146	139 136	134 134 1	7 144 154	166 162 15	160 133
57 5 -52 ⁹	Hydro	cyani	c 101	7	\times 1)—1 n		Trime	thyl- coniur	m To-	10	V 1	_1 n	267 2	22 187 1	167 149 1	141 137	135 136 1	146 157	171 176 170	176
	Hydro		C	7	X 1]-4		Uric	uomui	n lon		Ŷ i						Прт		LATTICE I	
	Hydro	oniu noniu	n Ion	9.1	V 10	<u>1</u> —7	l	Water	κ_	24°C		× 1		Li ⁺	60	Sr ⁺² Ba ⁺²	113	S ⁻² 1 Se ⁻² 1	84 (A)	l pegative	
												<u>^-</u>	-	Na+ K+	95 133	B+3	20	Te ⁻² 2:		F Cl 1030 84	
3. SOLUBILITY PR								CT C	ONS	CAN				Rb+	148	Al^{+3}	50	F- 1		914 77	728 €
	AgBr					C ³ O ⁴		× 10 ⁻⁸ × 10 ⁻¹				2×10^{-1}		Be ⁺²	31	N^{+3}			ST K	812 70	i 671 €
	AggCO AgCI	8	5 X	10-1	2 Bai 0 Ca	204 202		× 10-9				1 × 10 9 × 10		Mg ⁺² Ca ⁺²	- 65 99	P+3 0-2	212 140	_	95 Rb 16 Cs		2 654 t 9 613 t
	Ag ₂ Cr(0,			2 Ca		4 >	< 10 ⁻¹	1 Mg	NH, I	20.	2×10	0-18	<u> </u>							3 010 [
	Ag[Ag	(CN),]4 ×	10-1	2 Ca	C_2O_4	2 :	× 10-9	Mg	(OH)		L X 1	}	772	199			HALF			013
	Agi Ag ₃ PO	١.	1 X	10-1	6 Cd	S (OH)		× 10−2 × 10−2	o Pho	ີະດ. -		1 × 10				year L secs		140 1.28 1a45 16		Cs187	8.1 day
	Ag_2S	4	ix	10-5	Cu	(OH): S	1 1 2	< 10 ⁻⁸	6 PbS	3.						year		e59 4	5 days	4 Au 198	2.69 da
1	AgCNS		1 ×	10-1	2 Fe	(HO)	. 1 :	< 10-8	6 Pb\$	5O₄		2 X 1				hour		080	5.26 y	Ra ²²⁶	1620 vi
1	AI (OH BaCO ₃) 3	$2 \times$	10-3	2 Hg	$_2$ Br $_2$	3)	× 10-2	3 SrC	OH,	. 5	1 × 10	J-5	P82 S85		days	: B	r ⁸² 35.	hours	U235 /	7.1 × 10
Ī	3aCrO		3 X 1 ×	10-9	o Hg	$_{2}^{\text{Cl}_{2}}$	6 2	× 10-1 × 10-5	2 ZnS	CH)	2 J.C	i × 10 l × 10	յ_ւն Դ–24	C186		3 days × 105	Δ I:	129 17	years X 107v	Pu230	24 400 24 400
-											_						_				
				-	_	ja & S.							•	Alberta.	, ECID	otrioni			Pri	nted in Car	ADA
	1=1	r -		D.	J	NO.	2	E [⊕] (H.									4				~ 6 ↔.
	1	CHO	ocie	, 40	Her	,,-u	l			<u>. 6</u>				. ,		1	u^2	r, + 2-c-	=	Cu(s)	E=+0.
				+			> >	614.	4	t_ ¯	= 0) · C	00	1				_	•	•	

H+e- $\geq \frac{1}{2}$ H₂ E=0.000V Ca²⁺+ze \geq Cd(s) E=-0.246V ==-0.023V

,340