

**NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY**

FACULTY OF HEALTH, NATURAL RESOURCES AND APPLIED SCIENCES

DEPARTMENT OF BIOLOGY, CHEMISTRY AND PHYSICS

QUALIFICATION: BACHELOR OF SCIENCE	
QUALIFICATION CODE: 07BOSC	LEVEL: 6
COURSE CODE: APP601S	COURSE NAME: ANALYTICAL PRINCIPLES AND PRACTICE
SESSION: JUNE 2023	PAPER: THEORY
DURATION: 3 HOURS	MARKS: 100

FIRST OPPORTUNITY EXAMINATION QUESTION PAPER	
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MODERATOR:	DR MARIUS MUTORWA

ATTACHMENT

List of Useful Tables, Formulas and Constants

THIS EXAMINATION PAPER CONSISTS OF 9 PAGES (Including this front page and attachments)

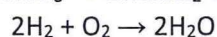
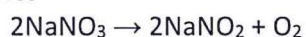
Question 1: Multiple Choice Questions

[30]

- 1.1 Which of the following glassware is not recommended for accurate measurements of volumes? (2)
- (A) A graduated cylinder
 - (B) A volumetric flask
 - (C) A volumetric pipette
 - (D) A measuring pipette
- 1.2 A chemical or physical principle that can be used to study an analyte is called (2)
- (A) A technique
 - (B) A procedure
 - (C) A protocol
 - (D) A method
- 1.3 The ability of an analytical balance to measure the smallest detectable increment of mass is called (2)
- (A) The balance accuracy
 - (B) The balance precision
 - (C) The balance sensitivity
 - (D) None of the above
- 1.4 In statistics, the precision of repeated measurements is characterised by (2)
- (A) The standard deviation
 - (B) The relative standard deviation
 - (C) The variance
 - (D) All of the above
- 1.5 An amphoteric substance (2)
- (A) Has neither acid or base properties
 - (B) Turns litmus paper red and blue
 - (C) Is insoluble in base, but dissolves in an acid
 - (D) Reacts with both an acid and a base
- 1.6 Consider the equilibrium reaction
- $$4\text{NH}_3(\text{g}) + 3\text{O}_2(\text{g}) \rightleftharpoons 2\text{N}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \quad \Delta H = -1268 \text{ kJ}$$
- Which change will cause the reaction to shift to the right? (2)
- (A) Increase the temperature
 - (B) Decrease the volume of the container.
 - (C) Add a catalyst to speed up the reaction.

(D) Remove the gaseous water by allowing it to react and be absorbed by KOH.

- 1.7 Sodium nitrate, heated in the presence of an excess of hydrogen, forms water according to the two-step process



From the reactions above, how many grams of sodium nitrate are required to form 9 grams of water? (2)

- (A) 21.3
- (B) 42.5
- (C) 69.0
- (D) 85.0

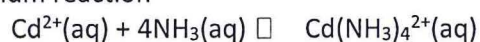
- 1.8 What is the molarity of the sulphate ion in a solution prepared by dissolving 17.1 g of aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3$, in enough water to prepare 1.00 L of solution? Neglect any hydrolysis. (2)

- (A) 1.67×10^{-2} M
- (B) 5.00×10^{-2} M
- (C) 1.50×10^{-1} M
- (D) 2.50×10^{-1} M

- 1.9 A reaction for which $\Delta H < 0$ and $\Delta S < 0$ is most likely to have which of these thermodynamic properties? (2)

- (A) The reaction cannot be spontaneous at any temperature.
- (B) The reaction will tend to be spontaneous at low temperatures.
- (C) The reaction will tend to be spontaneous at high temperatures.
- (D) The spontaneity of the reaction will be independent of temperature.

- 1.10 Consider the equilibrium reaction



The equilibrium constant of the reaction is called (2)

- (A) Overall formation constant
- (B) Stepwise formation constant
- (C) Cumulative formation constant
- (D) Both (A) and (C)

Question 2

[20]

A researcher at NUST investigated the quantitative determination of Cr in high-alloy steels using a potentiometric titration of Cr(VI). Before the titration, samples of the steel were dissolved in acid and the chromium oxidized to Cr(VI) using peroxydisulfate. Shown here are the results (as %w/w Cr) for the analysis of a reference steel.

16.968; 16.922; 16.840; 16.883; 16.887; 16.977; 16.857; 16.728

- 2.1 Calculate the mean of the measurements (to 5 significant figures). (2)
- 2.2 Determine the median of the measurements (2)
- 2.3 Calculate the standard deviation (2 significant figures). (2)
- 2.4 Calculate the relative standard deviation (in %) (2)
- 2.5 Comment on the precision of the measurements (2)
- 2.6 Calculate the 95% confidence interval about the mean. (4)
- 2.7 What does this confidence interval mean? (2)
- 2.8 One of the measured values appears to be an outlier. Identify that value and use The Dixon Q test to confirm whether that measurement is reliable at 95% confidence level. (4)

Question 3

[10]

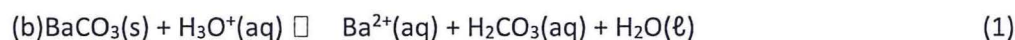
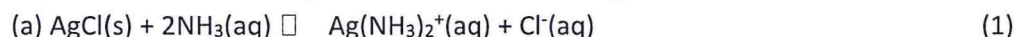
A 10.0-g sample containing an analyte is transferred to a 250-mL volumetric flask and diluted to volume. When a 10.0 mL aliquot of the resulting solution is diluted to 25.0 mL it gives signal of 0.235 (arbitrary units). A second 10.0-mL portion of the solution is spiked with 10.0 mL of a 1.0-ppm standard solution of the analyte and diluted to 25.0 mL. The signal for the spiked sample is 0.502.

- 3.1 What type of standardisation is used in this analysis? Explain your answer. (2)
- 3.2 Express ppm in gram per litre (g/L) (1)
- 3.3 Calculate the analyte concentration (in g/L) in the 10.00 ml aliquot. (3)
- 3.4 Calculate the gram of analyte in the 250 mL solution. (2)
- 3.5 Calculate the weight percent of analyte in the original sample. (2)

Question 4

[20]

4.1 Write equilibrium constant expressions for the following reactions.



4.2 Calculate the standard state potential and the equilibrium constant for the following

redox reaction: $\text{MnO}_4^- (\text{aq}) + \text{H}_2\text{SO}_3 (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq}) + \text{SO}_4^{2-} (\text{aq})$ acidic solution.

Assume that $[\text{H}_3\text{O}^+]$ is 1.0 M.

$$E^0 (\text{MnO}_4^- / \text{Mn}^{2+}) = +1.51 \text{ V} \text{ and } E^0 (\text{SO}_3^{2-} / \text{SO}_4^{2-}) = +0.172 \text{ V} \quad (8)$$

4.3 Calculate the ionic strength of a 0.050 M NaCl solution. (2)

4.4 Calculate the pH of the solution that results from the addition of 0.040 moles of HNO_3 to a buffer made by combining 0.500 L of 0.380 M $\text{HC}_3\text{H}_5\text{O}_2$ ($K_a = 1.30 \times 10^{-5}$) and 0.500 L of 0.380 M $\text{NaC}_3\text{H}_5\text{O}_2$. Assume addition of the nitric acid has no effect on volume. (8)

Question 5

[20]

Calculate the pH at each point listed below for the titration of 100.0 mL of 0.100 M cocaine, symbolised as "B", ($K_b = 2.6 \times 10^{-6}$) with 0.200 M HNO_3 . The points to calculate are at added HNO_3 volumes of 0.0, 10.0, 25.0, 50.0 and 60.0 mL.

5.1 0.0 mL of added HNO_3 (4)

5.2 10.0 mL of added HNO_3 (4)

5.3 25.0 mL of added HNO_3 (4)

5.4 50.0 mL of added HNO_3 (4)

5.5 60.0 mL of added HNO_3 (4)

END

Data Sheet

$$t_{\text{calculated}} = \frac{|\bar{x} - \mu|}{s} \sqrt{N} \quad t_{\text{calculated}} = \frac{\bar{d}}{S_d} \sqrt{n} \quad t_{\text{calculated}} = \frac{|\bar{X}_a - \bar{X}_b|}{S_{\text{pooled}}} \times \sqrt{\frac{n_a \times n_b}{n_a + n_b}}$$

$$S_{\text{pooled}} = \sqrt{\frac{s_a^2(N_a - 1) + s_b^2(N_b - 1) + \dots}{N_a + N_b + \dots - N_{\text{set of data}}}}$$

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{n}}$$

Confidence				
degrees Freedom	50%	90%	95%	99%
1	1.000	6.314	12.706	63.656
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
4	0.741	2.132	2.776	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845
21	0.686	1.721	2.080	2.831
22	0.686	1.717	2.074	2.819
23	0.685	1.714	2.069	2.807
24	0.685	1.711	2.064	2.797
25	0.684	1.708	2.060	2.787
26	0.684	1.706	2.056	2.779
27	0.684	1.703	2.052	2.771
28	0.683	1.701	2.048	2.763
29	0.683	1.699	2.045	2.756
30	0.683	1.697	2.042	2.750
31	0.682	1.696	2.040	2.744
32	0.682	1.694	2.037	2.738
33	0.682	1.692	2.035	2.733
34	0.682	1.691	2.032	2.728
35	0.682	1.690	2.030	2.724

Critical Values for the Rejection Quotient

N	Q _{crit} (Reject if Q _{exp} > Q _{crit})		
	90% Confidence	95% Confidence	99% Confidence
3	0.941	0.970	0.994
4	0.765	0.829	0.926
5	0.642	0.710	0.821
6	0.560	0.625	0.740
7	0.507	0.568	0.680
8	0.468	0.526	0.634
9	0.437	0.493	0.598
10	0.412	0.466	0.568

N = number of observations

F(0.05, σ_{num}, σ_{denom}) for a Two-Tailed F-Test													
$\sigma_{num} \Rightarrow$	1	2	3	4	5	6	7	8	9	10	15	20	∞
$\sigma_{den} \Downarrow$													
1	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
2	38.51	39.00	39.17	39.25	39.30	39.33	39.36	39.37	39.39	39.40	39.43	39.45	39.50
3	17.44	16.04	15.44	15.10	14.88	14.73	14.62	14.54	14.47	14.42	14.25	14.17	13.90
4	12.22	10.65	9.979	9.605	9.364	9.197	9.074	8.980	8.905	8.444	8.657	8.560	8.257
5	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
6	8.813	7.260	6.599	6.227	5.988	5.820	5.695	5.600	5.523	5.461	5.269	5.168	4.894
7	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
8	7.571	6.059	5.416	5.053	4.817	4.652	4.529	4.433	4.357	4.259	4.101	3.999	3.670
9	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
10	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
11	6.724	5.256	4.630	4.275	4.044	3.881	3.759	3.644	3.588	3.526	3.330	3.226	2.883
12	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
13	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
14	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
15	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
16	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
17	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
18	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
19	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
20	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

Physical Constants

Gas constant	R	= 8.315 J K ⁻¹ mol ⁻¹ = 8.315 kPa dm ³ K ⁻¹ mol ⁻¹ = 8.315 Pa m ³ K ⁻¹ mol ⁻¹ = 8.206 x 10 ⁻² L atm K ⁻¹ mol ⁻¹
Boltzmann constant	k	= 1.381 x 10 ⁻²³ J K ⁻¹
Planck constant	h	= 6.626 x 10 ⁻³⁴ J K ⁻¹
Faraday constant	F	= 9.649 x 10 ⁴ C mol ⁻¹
Avogadro constant	L or N_A	= 6.022 x 10 ²³ mol ⁻¹
Speed of light in vacuum	c	= 2.998 x 10 ⁸ m s ⁻¹
Mole volume of an ideal gas	V_m	= 22.41 L mol ⁻¹ (at 1 atm and 273.15 K) = 22.71 L mol ⁻¹ (at 1 bar and 273.15 K)
Elementary charge	e	= 1.602 x 10 ⁻¹⁹ C
Rest mass of electron	m_e	= 9.109 x 10 ⁻³¹ kg
Rest mass of proton	m_p	= 1.673 x 10 ⁻²⁷ kg
Rest mass of neutron	m_n	= 1.675 x 10 ⁻²⁷ kg
Permittivity of vacuum	ϵ_0	= 8.854 x 10 ⁻¹² C ² J ⁻¹ m ⁻¹ (or F m ⁻¹)
Gravitational acceleration	g	= 9.807 m s ⁻²

Conversion Factors

1 W	= 1 J s ⁻¹
1 J	= 0.2390 cal = 1 N m = 1 V C = 1 Pa m ³ = 1 kg m ² s ⁻²
1 cal	= 4.184 J
1 eV	= 1.602 x 10 ⁻¹⁹ J
1 L atm	= 101.3 J
1 atm	= 1.013 x 10 ⁵ N m ⁻² = 1.013 x 10 ⁵ Pa = 760 mmHg
1 bar	= 1 x 10 ⁵ Pa
1 L	= 10 ⁻³ m ³ = 1 dm ³
1 Angstrom	= 1 x 10 ⁻¹⁰ m = 0.1 nm = 100 pm
1 micron (μ)	= 10 ⁻⁶ m = 1 μm
1 Poise	= 0.1 Pa s = 0.1 N sm ⁻²
1 ppm	= 1 μg g ⁻¹ = 1 mg kg ⁻¹ = 1 mg L ⁻¹ (dilute aqueous solutions only)

$$\frac{S_{\text{samp}}}{C_A \frac{V_o}{V_f}} = \frac{S_{\text{spike}}}{C_A \frac{V_o}{V_f} + C_{\text{std}} \frac{V_{\text{std}}}{V_f}}$$

$$\frac{S_{\text{samp}}}{C_A} = \frac{S_{\text{spike}}}{C_A \frac{V_o}{V_o + V_{\text{std}}} + C_{\text{std}} \frac{V_{\text{std}}}{V_o + V_{\text{std}}}}$$

$$\Delta G^{\circ} = -RT \ln K \quad E^{\circ} = \frac{0.05916}{n} \log K \quad E^{\circ} = E^{\circ}_{\text{red}} - E^{\circ}_{\text{ox}} \quad E = E^{\circ} - \frac{0.05916}{n} \log Q$$

PERIODIC TABLE OF THE ELEMENTS

1																	18
1 H 1.00794																	2 He 4.00260
3 Li 6.941	2 Be 9.01218											13 B 10.81	14 C 12.011	15 N 14.0067	16 O 15.9994	17 F 18.9984	18 Ne 20.179
11 Na 22.9898	12 Mg 24.305											13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.8
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.6	53 I 126.9	54 Xe 131.29
55 Cs 132.905	56 Ba 137.33	71 Lu 174.967	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.908	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.025	103 Lr (260)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (268)	110 Uun (269)	111 Uuu (272)	112 Uub (269)		114 Uuq		116 Uuh		118 Uuo

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Lanthanides:	57 La 138.906	58 Ce 140.12	59 Pr 140.908	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 161.930	68 Er 167.26	69 Tm 166.934	70 Yb 173.04
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Actinides:	89 Ac 227.028	90 Th 232.038	91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)
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