UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF CHEMISTRY

MODULE **CEM1A3E/3EA1**
INTRODUCTION TO GENERAL CHEMISTRY

CAMPUS **APK**

EXAM **29 MAY 2019**

DATE: **SESSION:**

JULY 08:00 – 11:00

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INTERNAL MODERATOR DR A ADEYINKA

DURATION 2½ HOURS **MARKS 82**

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY:

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1. THIS PAPER CONSISTS OF 8 PAGES AND A PERIODIC TABLE.

2. ANSWER ALL QUESTIONS.

3. ALL ANSWERS MUST BE GIVEN TO THE **CORRECT NUMBER OF SIGNIFICANT FIGURES.**

4. THE USE OF CELL PHONES AND OTHER ELECTRONIC COMMUNICATION DEVICES IS **FORBIDDEN** AND THEY MUST BE SWITCHED OFF. NO DATA/IMAGE STORING DEVICES, INCLUDING CALCULATORS CAPABLE OF SUCH, ARE PERMITTED IN THIS EXAMINATION.

5. THIS IS A CLOSED BOOK EXAMINATION. YOU ARE **NOT ALLOWED** TO HAVE ANY BOOK, MEMORANDUM, NOTES, PAPER, PHOTOGRAPHS, DOCUMENT OR WRITTEN/PRINTED MATERIAL OTHER THAN THE QUESTION PAPER AND THE ANSWER BOOKS PROVIDED BY THE EXAMINER/INVIGILATOR. IF YOU NEED PAPER FOR ROUGH WORK, AN ADDITIONAL EXAM ANSWER SHEET WILL BE GIVEN TO YOU, WHICH MUST BE CLEARLY LABELLED AS **ROUGH WORK: NOT FOR MARKING**, AND HANDED IN TOGETHER WITH THE QUESTION PAPER AND ALL YOUR ANSWER BOOKS.

SECTION A [26 Marks] [Multi choice questions: Only one answer is correct]

1. When the cations Na^+, K^+, Rb^+, Cs^+ are combined with chloride ion in the gas phase to form ion pairs, which pair formation releases the greatest amount of energy?
   A. NaCl
   B. KCl
   C. RbCl
   D. CsCl
   E. All release the same amount of energy.

2. Which of the following processes is not exothermic?
   A. $Cs^+(g) + e^- \rightarrow Cs(g)$
   B. $F(g) + e^- \rightarrow F^-(g)$
   C. $Cs^+(g) + F^-(g) \rightarrow CsF(s)$
   D. $Cs(g) \rightarrow Cs(s)$
   E. $\frac{1}{2}F_2(g) \rightarrow F(g)$

3. Which set of ions are isoelectronic in their ground-state electron configurations?
   A. Na^+, K^+, Rb^+, Cs^+
   B. Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}
   C. N, O, F, Ne
   D. F^-, Cl^-, Br^-, I^-
   E. N^{3-}, O^{2-}, Mg^{2+}, Al^{3+}

4. The Lewis structure for each of the following except ____contains at least one double bond.
   A. CS_2
   B. NO^+
   C. C_2H_4
   D. N_2H_2
   E O_2

5. For each of the following species except ____, the electronic structure may be adequately described by two resonance formulas.
   A. O_3
   B. SO_2
   C. NO_2^-
   D. SO_3^{2-}
   E C_6H_6

6. In which of the following molecules is the octet rule violated?
   A. PF_3
   B. SiF_4
   C OF_2
   D. ClF_3
   E ClF

7. From a consideration of the Lewis structure of the thiocyanate ion, SCN^-, in which carbon has a double bond with both the sulfur and nitrogen atoms, the formal charges on the sulfur, carbon, and nitrogen atoms are, respectively,
   A. –1, 0, 0.
   B 0, 0, –1.
   C –1, +1, –1.
   D –2, +1, 0.
   E –2, 0, +1.

8. Which molecule or ion has the same molecular geometry for its central atom as the carbonate ion?
   A. BrO_3^-
   B. $AsCl_3$
   C. CH_3^-
   D. H_2CO
   E. PF_3

9. The reaction quotient for a system is 7.2×10^2. If the equilibrium constant for the system is 36, what will happen as equilibrium is approached?
   A. There will be a net gain in product.
   B. There will be a net gain in reactant.
   C. There will be a net gain in both product and reactant.
   D. There will be no net gain in either product or reactant.
   E The equilibrium constant will decrease until it equals the reaction quotient.

10 Which of the following statements is <u>incorrect</u> concerning the addition of a catalyst to an equilibrium reaction system?
   A. The catalyst increases the rate of both the forward and the reverse reaction.
   B. If the reactants are capable of forming many different products, a catalyst may selectively speed up one reaction over another.
   C. The catalyst speeds up the attainment of equilibrium.
   D. The catalyst increases the yield of the products.
   E. The catalyst is not consumed in either the forward or the reverse reaction.

11. In the following list of pairs of ions, which is the more acidic ?

Fe^{2+} or Fe^{3+}; Cu^{2+} or Cu^{+}; Co^{2+} or Co^{3+}

A. Fe^{3+}, Cu^{+}, Co^{2+}

B. Fe^{2+}, Cu^{2+}, Co^{3+}

C. Fe^{3+}, Cu^{2+}, Co^{3+}

D. Fe^{2+}, Cu^{2+}, Co^{2+}

E. None of the above

12. Which acid/base definition best fits this reaction?

$$H_2SO_4\ (aq) + NaOH\ (aq) \rightarrow NaHSO_4\ (aq) + H_2O\ (l)$$

A. Lewis

B. Brønsted-Lowry

C. Arrhenius

D. All of the above

E. None of the above

13. Which of the following statements is true concerning the two compounds 2,3-dimethylpentane and 2,4-dimethylpentane?

A. Because the two compounds are structural isomers, they should have identical physical properties.
B. Because the two compounds are structural isomers, they should have the same molecular formula.
C. Because the two compounds are structural isomers, they should have identical chemical properties.
D. Because the two compounds are geometric isomers, one should be *cis* and the other should be *trans*.
E. Because the two compounds are enantiomers, they should rotate polarized light in opposite directions.

SECTION B [56 Marks] [Answer all Questions]

Question 1 [9 Marks]

1.1 Which has a larger radius S or S^{2-}? Explain. (3)

1.2 With the aid of formal charges, draw the best representative Lewis structure for the sulphurous acid molecule H_2SO_3. **Show all steps** of how you reach your conclusion. (6)

Question 2 [11 Marks]

2.1 Explain in detail why nitrogen trifluoride NF_3 has a smaller dipole moment than NH_3 although N-F bonds are more polar than the N-H bonds and both structures trigonal pyramidal. Use Lewis structures to clarify your answer. (5)

2.2

(a) Draw the Lewis structure of XeF_2O (3)
(b) What is the electron domain geometry of XeF_2O ? (1)
(c) What is the molecular geometry of XeF_2O ? (1)
(d) By visually analysing the Lewis structure you have drawn, determine the hybridisation of XeF_2O. (1)

Question 3 [10 Marks]

3.1 A bacterial culture isolated from sewage produced 35.5 mL of methane, CH_4, at 31 °C and 753 mmHg. What is the volume of this methane at standard temperature and pressure (0 °C, 760 mmHg)? (4)

3.2 (a) Calculate the density of helium, He, in grams per litre at 21 °C and 752 mm Hg. The density of air under these conditions is 1.188 g/L. (5)

(b) What is the difference in mass between 1 litre of air and 1 litre of helium? (Hint: the mass difference is equivalent to the buoyant, or lifting, force of helium per litre). (1)

Question 4 [9 Marks]

Phosphorous pentachloride, PCl_5, decomposes when heated.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

If the initial concentration of PCl_5 is 1.00 mol/L, what is the equilibrium composition of the gaseous mixture at 160 °C? The equilibrium constant Kc at 160 °C is 0.0211

Question Five [10 Marks]

5.1 Explain why for the series of oxoacids, $HClO$,$HClO_2$,$HClO_3$,$HClO_4$ the acid strength increases from left to right. (2)

5.2 Define an acid and a base according to the Lewis concept. Give an example of such an acid-base equation and identify each species as an acid or base. (4)

5.3 Decide whether aqueous solutions of NaF is basic, acidic or neutral. Use equation(s) to help explain your answer. (4)

Question 6 [7 Marks]

6.1 Write an equation for a possible substitution reaction of ethane, C_2H_6, with Cl_2. (2)

6.2 Complete the following equation, giving only the main product. (1)

$$CH_2{=}CHCH_3 + H{-}OH \xrightarrow[\text{catalyst}]{H_2SO_4}$$

6.3 Redraw the structure, circle and name the functional group in each of the following compounds. (4)

a. $CH_3{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}CH_2CH_2CH_3$ **b.** $CH_3{-}\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle OH}{|}}{C}}{-}CH_2CH_3$

c. $HO{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}CH_2CH_3$ **d.** $H{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}CH_2CH_3$

The Periodic Table

Period	1	2	3	4	5	6	7	8	9	10	11	12	13/III	14/IV	15/V	16/VI	17/VII	18/VIII
	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	La-Lu	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 210.0	85 At 210.0	86 Rn 222.0
7	87 Fr 223.0	88 Ra 226.0	Ac-Lr	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	.....								

Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 144.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 239.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 252.1	99 Es 252.1	100 Fm 257.1	101 Md 256.1	102 No 259.1	103 Lr 260.1

s block *d* block *p* block *f* block

TABLE 15.2 Relative Strengths of Acids and Bases

	Acid	Base	
Strongest acids	$HClO_4$	ClO_4^-	Weakest bases
	H_2SO_4	HSO_4^-	
	HI	I^-	
	HBr	Br^-	
	HCl	Cl^-	
	HNO_3	NO_3^-	
	H_3O^+	H_2O	
	HSO_4^-	SO_4^{2-}	
	H_2SO_3	HSO_3^-	
	H_3PO_4	$H_2PO_4^-$	
	HNO_2	NO_2^-	
	HF	F^-	
	$HC_2H_3O_2$	$C_2H_3O_2^-$	
	$Al(H_2O)_6^{3+}$	$Al(H_2O)_5OH^{2+}$	
	H_2CO_3	HCO_3^-	
	H_2S	HS^-	
	$HClO$	ClO^-	
	$HBrO$	BrO^-	
	NH_4^+	NH_3	
	HCN	CN^-	
	HCO_3^-	CO_3^{2-}	
	H_2O_2	HO_2^-	
	HS^-	S^{2-}	
Weakest acids	H_2O	OH^-	Strongest bases

CONSTANTS

Gas constant = 0.08206L•atm/K•mol