FINAL	%	

UNISA university of south africa

CHE1501

MAY/JUNE 2015

GENERAL CHEMISTRY 1A

STUDENT NUMBER									

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Subject

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UNIVERSITY EXAMINATIONS

UNIVERSITEITSEKSAMENS

UNISA university of south africa

CHE1501

May/June 2015

GENERAL CHEMISTRY IA

Duration 2 Hours

100 Marks

EXAMINERS :

FIRST	MR MG SMITH
SECOND	MR ME APHANE

Use of a non-programmable pocket calculator is permissible.

Closed book examination

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The above-mentioned calculator may be a SCIENTIFIC calculator.

This paper consists of 17 pages (including this page)

Five pages are attached for rough work (pg. 11-15)
A table of physical constants and conversion factors is included (pg. 16).
A periodic table is attached (pg 17)

Answer all the Questions

Fill in the answers on the question paper

Show all your calculations.

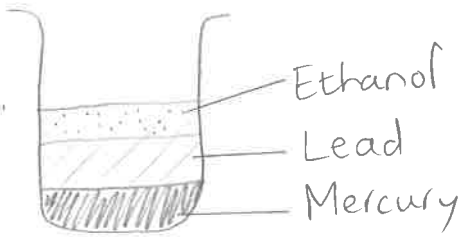
Write the correct units at each step in your calculations and answers

NB: Marks will be deducted for incorrect or missing units

1. a) Mercury, ethanol and molten lead are poured into a container Three distinct layers are formed. The densities of the threes substances are:

Mercury: 13 55 g/cm^3
Ethanol: 0.78 g/cm^3
Lead: 11 4 g/cm^3

Sketch the container with the three layers and identify the substance in each layer (2)



b) Predict the formula of the ionic compound formed by magnesium with iodine (2)

MgI_2

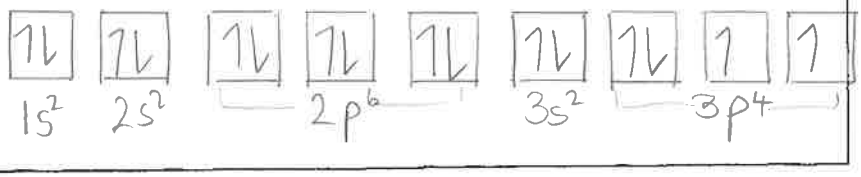
c) (i) What is the electron configuration of the sulfide ion? (2)

1s
2s2p
3s3p3d

S^{2-} = 16 + 2 electrons ∴ $1s^2 2s^2 2p^6 3s^2 3p^6$
= 18 electrons

(ii) Draw the energy orbital diagram of the sulfur atom. (4)

S = 16 electrons



[10]

2 a) What would be the empirical formula of a compound consisting of C, H, and O in a mole ratio of 1.00 C . 3.33 H · 1 00 O? x 3 = 3C, 10H, 3O (2)

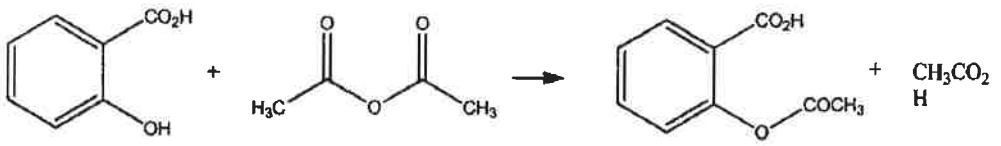
$C_3H_{10}O_3$

b) Nitric acid is extensively used in the manufacturing of fertilizer A bottle containing 75.0 mL of nitric acid solution is labeled 6.0 *M* nitric acid
How many moles of nitric acid are in the bottle? (4)

Molarity = $\frac{\text{moles solute}}{\text{Volume}}$

∴ moles of solute = Molarity × Volume = 6.0M × 0.075L = 0.45 moles of nitric acid

c) Suppose you prepare a sample of aspirin by heating 10 g of salicylic acid with an excess of acetic anhydride. You obtain 6.2 g of pure aspirin. What is the percentage yield of the reaction? Hint. First calculate the theoretical yield.



Salicylic Acid M_r = 138 g/mol | Acetic Anhydride M_r = 102 g/mol | Aspirin M_r = 180 g/mol | Acetic Acid M_r = 60 g/mol

(6)

- no. moles salicylic acid = $\frac{10.0\text{ g}}{138\text{ g/mol}}$ = 0.07246 mol
- Limiting reagent = salicylic acid
- Theoretical yield aspirin = no moles limiting reagent × molar ratio (product : limiting reagent) × molar mass product
  = 0.07246 mol salycilic acid × $\frac{1}{1}$ × 180 g/mol aspirin
  = 13.043 g
- Percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}}$ × 100
  = 48 %

[12]

3 a) Write a net ionic equation for the *precipitation reaction* that occurs when solutions of NaOH and $Cu(NO_3)_2$ are mixed (4)

① Write balanced equation
② Write (aq) substances in ionic form
③ Cancel spectator ions.

$2NaOH_{(aq)} + Cu(NO_3)_{2(aq)} \rightarrow Cu(OH)_{2(s)} + 2NaNO_{3(aq)}$

$2Na^{+}_{(aq)} + 2OH^{-}_{(aq)} + Cu^{2+}_{(aq)} + 2NO_3^{-}_{(aq)} \rightarrow Cu(OH)_{2(s)} + 2Na^{+}_{(aq)} + 2NO_3^{-}$

$\therefore Cu^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Cu(OH)_{2(s)}$

Oxidation. Reduction

b) Consider the following balanced redox reaction in basic medium.

O I L R I G

$$3Sn^{2+}(aq) + Cr_2O_7^{2-}(aq) + 4H_2O(l) \rightarrow 3Sn^{4+}(aq) + Cr_2O_3(s) + 8OH^{-}(aq)$$

(+2) (+6) (+4) (+3)

+12 −14 −2 +6 −6

(i) What is the oxidizing agent? (2)

$Cr_2O_7^{2-}$

(ii) Which element increases in oxidation number? (2)

Sn

(iii) What species contains the element with the highest oxidation number? (2)

$Cr_2O_7^{2-}$

(iv) If the reaction were to take place in acidic medium, what species would not be included in the reaction? (2)

OH^-

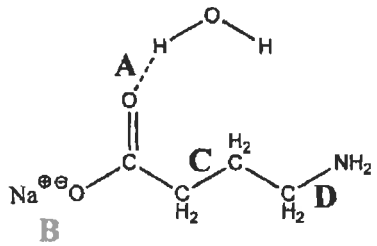
[12]

4 a) What type of electron orbital (i e s, p, d or f) is designated by the following set of quantum numbers

$\mathbf{n} = 2, l = 1, \mathbf{m}_l = -1$ (2)

p

b) Consider the molecules below. Each of A, B, C and D, represent a different type of bond Identify A, B, C and D as either non-polar covalent, polar covalent, dative covalent, ionic or hydrogen bonds



(4)

A - hydrogen bond (between H and O)
B - ionic (between cation, Na^+ and anion O^-)
C - non-polar covalent (same electronegativity C-C)
D - polar covalent (different electronegativity C-N) (higher

c) Give the symbol of the most electronegative halogen (2)

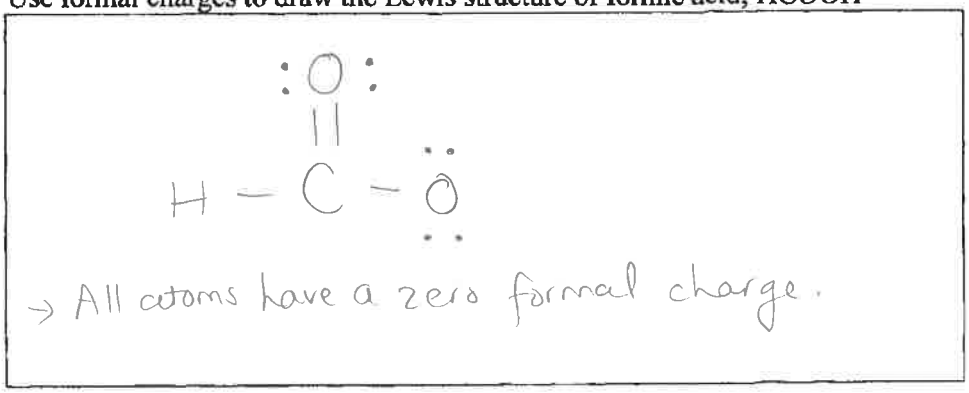
F

d) Give the element in period 4 whose +2 ion is isoelectronic with Argon (2)

Ca

[10]

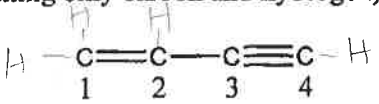
5. a) Use formal charges to draw the Lewis structure of formic acid, HCOOH (4)



b) What is the molecular geometry of ammonia? NH_3 (2)

Trigonal pyramidal

c) The *partial* Lewis structure shown below is the carbon framework for a hydrocarbon molecule (containing only carbon and hydrogen).

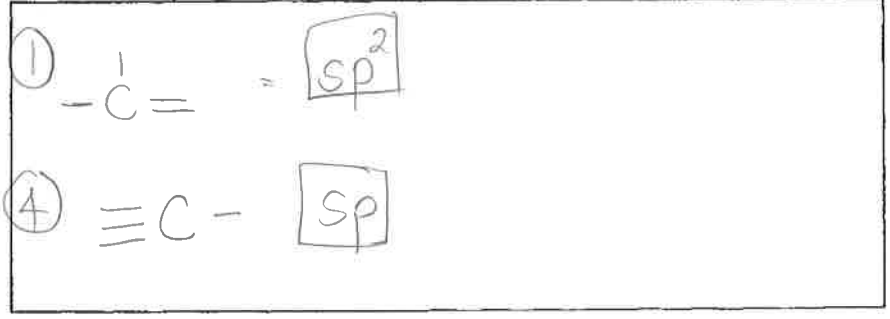


In the *full* Lewis structure, each carbon atom satisfies the octet rule, and there are no unshared electron pairs in the molecule The carbon atoms are labeled 1, 2, 3 and 4

(i) How many hydrogen atoms are there in the molecule? (2)

4

(ii) What is the hybridization of each of the carbon atoms 1 and 4? (4)



No overall dipole moment
∴ unlikely to be a lone pair
3 bonds = trigonal planar
5 lone pairs

d) Consider an AB_3 molecule in which A and B differ in electronegativity. You are told that the molecule has no overall dipole moment Which one of the following could be the molecular geometry of the molecule?

× 3 + lone pair × 5 bonds × 4 bonds

Trigonal pyramidal, trigonal planar, T-shaped, or tetrahedral? (2)

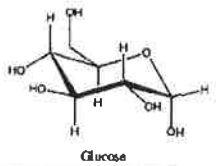
Trigonal Planar

e) The molecule called diazine has the formula N_2H_2 and the Lewis structure:

Do you expect diazine to be a linear molecule? Briefly explain your answer using VSEPR theory If not, do you expect the molecule to be planar? (5)

NO, not linear.
There are 3 areas of electron density around the central molecule, all 3 of which are bonds (no lone electron pairs). This equates to an AX_3 molecular geometry, which is Trigonal Planar

f) Suppose the hydrogen atoms on the OH groups in glucose were replaced with methyl groups, CH_3 Would you expect the water solubility of the resulting molecule to be higher than, lower than, or about the same as glucose?



Glucose

(2)

Lower.
There would no longer by hydrogen bonding with water as CH_3 has no O atoms.
The hydrogen bonds (which are weak bonds) contributed to the water solubility of glucose

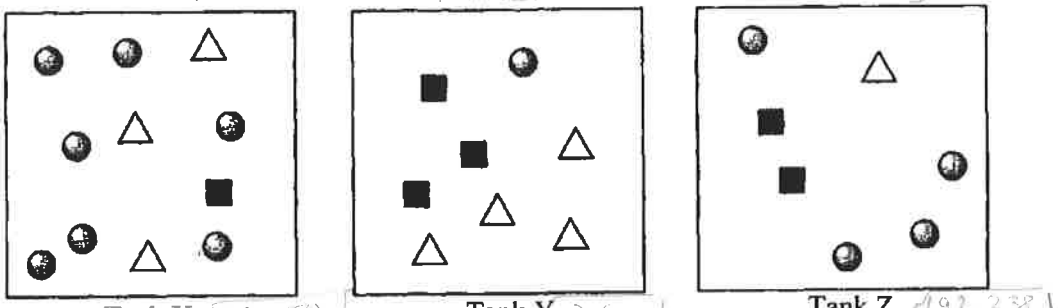
[21]

● CH_4 = 16.042 g/mol.
□ O_2 = 32.00 g/mol.
△ SO_2 = 64.07 g/mol.

6 a) Consider three sealed tanks, labeled X, Y and Z Each tank has the same volume and the same temperature In each tank, one mole of CH_4 is represented by a circle, one mole of oxygen, O_2 by a square, and one mole of SO_2 by a triangle Assume that no reaction takes place between these molecules·

pressure density
$P = \frac{\rho RT}{M}$
M - molar mass

11 moles 9 moles 7 moles



Tank X 336.504 Tank Y 368.041 Tank Z 192.238

$7 \times CH_4 = 112.294$
$1 \times O_2 = 32$
$3 \times SO_2 = 192.21$

$1 \times CH_4 = 16.042$
$3 \times O_2 = 96$
$4 \times SO_2 = 256$

$4 \times CH_4 = 64.168$
$2 \times O_2 = 64$
$1 \times SO_2 = 64.07$

(i) In which tank is the total pressure highest? (2)

Tank Y - It contains the largest amount of gaseous mixture.

(ii) In which tank is the partial pressure of SO_2 highest? (2)

Tank Y - Of all tanks, Tank Y has the highest amount of SO_2 relative to other gases.

iii) In which tank is the mass of all three gases the same? (3)

Tank Z

$4 \times CH_4 = 64.168$ g/mol
$\approx 2 \times O_2 = 64$ g/mol
$\approx 1 \times SO_2 = 64.07$ g/mol

(iv) Which tank has the heaviest contents? (3)

Tank Y

368.041 g/mol > 336.504 g/mol > 192.238 g/mol
(Tank Y) (Tank X) (Tank Z)

[10]

7 a) (i) Ammonia is produced by the reaction between nitrogen gas, N_2, and hydrogen gas, H_2 Write a balanced equation for this reaction using smallest whole-number coefficients for the reaction (2)

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

(ii) Write an expression for the rate of the reaction in terms of $\Delta[NH_3]$ (2)

Rate of reaction $= \frac{\Delta[NH_3]}{2t}$

(iii) The concentration of ammonia increases from 0 257 *M* to 0.815 *M* in 900 seconds Calculate the average rate of reaction over this time interval (4)

Rate of reaction $= \frac{\Delta[NH_3]}{2t} = \frac{0.815M - 0.257M}{2(900s)}$
$= 3.1 \times 10^{-4}$ Mol/L.S

b) The equilibrium constant for the reaction

$$2NO(g) + Br_2(g) \leftrightarrows 2NOBr(g)$$

is $K_c = 0.013$ at 1000K.

(i) At this temperature, does the equilibrium favour NO and Br_2, or does it favour NOBr? How do you know? (4)

If $K_c < 1$ reactants dominate at equilibrium.
Thus, the equilibrium favours NO & Br.

(ii) Calculate, K_c for the reverse reaction, i e. for $2NOBr(g) \leftrightarrows 2NO(g) + Br_2(g)$ (2)

K_c for reverse reaction = inverse of K_c for forward reaction
$= \frac{1}{K_c} = \frac{1}{0.013} = 76.92$

[14]

8 a) What two ions are central to the Arrhenius definitions of acids and bases? (2)

H^+ and OH^-

b) Why is acetic acid, CH_3COOH, a Brønsted-Lowry acid? (2)

Because it is a proton (H^+) donor, i.e. it can donate a proton (H^+) to another substance (to become CH_3COO^-, as conjugate base)

c) Given that $HClO_4$ is a strong acid, how would you classify the basicity of ClO_4^-? (2)

Weak.

$HClO_4$ is a strong acid, ∴ it forms a weak conjugate base

d) Briefly explain the chemistry of how sulphur dioxide, SO_2, contributes to the formation of acid rain Include relevant chemical equations (5)

* SO_2 (sulphur dioxide) is found naturally in the environment due to forest fires + volcanic eruptions.
* But increased burning of fossil fuels by humans has drastically increased atmospheric SO_2 levels.
* SO_2 oxidises into SO_3 (sulphur trioxide) which dissolves into H_2SO_4 (sulphuric acid) in rainwater.

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4$

* H_2SO_4 makes rainwater highly acid, forming what we know as acid rain. (pH of 4 or less). Normal rainwater has a slightly acidic pH of 5.6 (due to carbonic acid produced from dissolved CO_2)
* Water with pH below 4 cannot sustain life as very few organisms will survive in it.
* To combat this, we need to reduce the production of SO_2 + CO_2 from fossil fuel burning.

[11]

TOTAL OF PAPER: 100 MARKS

ROUGH WORK

ROUGH WORK

ROUGH WORK

PHYSICAL CONSTANTS:

Constant	Symbol	Value
Atomic mass unit	amu	1.66054×10^{-27} kg
Avogadro's number	N	$6\ 02214 \times 10^{23}$ mol^{-1}
Boltzmann constant	k	$1\ 38066 \times 10^{-23}$ J K^{-1}
Charge of an electron	e	$1\ 60218 \times 10^{-19}$ C
Gas constant	R	0 08206 L.atm K^{-1} mol^{-1} 8.31451 J.K^{-1}.mol^{-1}
Mass of an electron	m_e	$5\ 48580 \times 10^{-4}$ amu
Mass of a neutron	m_n	1 00866 amu
Mass of a proton	m_p	1 00728 amu
Planck's constant	h	$6\ 626 \times 10^{-34}$ Js
Speed of light	c	$2\ 9979 \times 10^{8}$ m s^{-1}
Natural logarithm	e	2.71828

CONVERSION FACTORS:

Temperature K = °C + 273

Pressure 1 atm = 101 325 kPa

1 atm = 760 Torr

1 atm = 760 mmHg

1 L = 1000 mL

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Periodic Table of Elements

1 1A																	18 VIIIA
1 H 1 008	2 IIA						1 H 1 008	Atomic number Symbol Atomic weight				13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	2 He 4 003
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
11 Na 22 99	12 Mg 24 31	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 Al 26 98	14 Si 28 09	15 P 30 97	16 S 32 07	17 Cl 35 45	18 Ar 39 95
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 59	33 As 74 92	34 Se 78 96	35 Br 79 90	36 Kr 83 80
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)	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
55 Cs 132 9	56 Ba 137 3	57 La* 138 9	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)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac** (227)	104 Unq (257)	105 Unp (260)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

*Lanthanides	58 Ce 140 1	59 Pr 140 9	60 Nd 144 2	61 Pm (147)	62 Sm 150 4	63 Eu 152 0	64 Gd 157 3	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	90 Th 232 0	91 Pa (231)	92 U 238 0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lw (257)