THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

TEST 1 – 13th July 2014

COURSE CODE – CH 110 /CH 120/ FO 130

TIME ALLOWED: TWO (02) HOURS

INSTRUCTIONS TO CANDIDATES:

1. *This paper comprises 3 questions, and is printed on pages 2, 3 and 4. Candidates are expected to attempt* ***ALL*** *questions.*
2. *Each question carries* ***twenty (20)*** *marks.*
3. *Candidates are reminded of the need for the* ***clear presentation*** *in their answers.*
4. *All the parts of a question should be answered* ***strictly in continuation***.
5. *A* ***table of constants and the periodic table are provided*** *on pages 5 and 6, respectively.*

QUESTION ONE (*Introduction*) 3.855×10^5 **[15 Marks]**

a. Use exponential notation to express the number 385,500 to:
   (i) one significant figure.
   (ii) three significant figures. [1]

b. Perform the following mathematical operations, and express each result to the correct number of significant figures.
   (i) $(6.404 \times 2.91) \div (18.7 - 17.1)$
   (ii) $\frac{2.526}{3.1} + \frac{0.470}{0.623} + \frac{80.705}{0.4326}$ [2]

c. A star is estimated to have a mass of 2×10^{36}kg. Assuming it to be a sphere of average radius 7.0×10^5km, calculate the average density of the star in units of grams per cubic centimeter. [2]

d. Diamonds are measured in carats, and 1 carat = 0.200 g. The density of diamond is 3.51 g/cm^3.
   (i) What is the volume of a 5.0-carat diamond? [2]
   (ii) What is the mass in carats of a diamond measuring 2.8 mL? [2]

e. In a scientific method, what is the importance of formulating a hypothesis? [1]

f. Define the terms
   (i) Nuclide (ii) Nucleon (iii) Mass Number (iv) Isotopes [4]

g. One isotope of copper is ^{65}Cu. Give the number of its neutrons and protons. [2]

h. What decimal fraction of a second is a pico-second, ps? [1]

i. The ideal gas equation is given by PV = nRT, where P is pressure in Newton per square area, V is volume, n is the number of moles, T is temperature and R is the gas constant. Show by units analysis that the derived unit of R = Joule·mol^{-1}·K^{-1}. [3]

4.9×10^{11} $\frac{f}{A}$

QUESTION TWO (*Atomic Theory*) [20 Marks]

a. The atomic weight of copper is 63.646 amu. The two naturally occurring isotopes of copper have the following masses: ^{63}Cu, 62.9298 amu; ^{65}Cu, 64.9278 amu. Calculate the percent abundance of ^{65}Cu in nature. [2.5]

b. State each of the following:
(i) Heisenberg uncertainty principle (ii) Pauli exclusion principle
(iii) Hund's rule (iv) Electron affinity (v) Electronegativity [2.5]

c. In the electronic configuration representation $3d^5$;
(i) What does each of the numbers 3 and 5 represent? [2]
(ii) Which quantum number is represented by the symbol "d"? [1]

d. Copper is the 29th element in the periodic table of elements, for copper:
(i) Give the ground state electronic configuration [2]
(ii) Draw the orbital diagrams for the electronic configuration in d(i) above [2]
(iii) Give the set of the four quantum numbers for the 3rd electron in ground state of copper [1]
(iv) Give the set of the four quantum numbers for the 19th electron in ground state of copper. [1]
(v) Which electron in the ground state of copper has the following set of the four quantum numbers; (3, 0, 0, -½) [1]

e. Calculate the;
(i) Energy difference in joules between n=1 and n=5 principal energy levels of a hydrogenic atom. [2]
(ii) de Broglie wavelength of a boy of mass 10.5 kg experiencing translational motion at 18 km/h. [3]

1s
2s 2p
3s 3p 3d
4s 4p 4 4f
5s 5p 5 5f
6s 6p 6
7s 7p

29
12
11

$1s^2$ 2

109678 cm

QUESTION THREE (*Chemical Bonding and Molecular Geometry*) [20 Marks]

a. Using Lewis symbols, diagram the reaction between
   (i) magnesium and oxygen atoms to give the ionic compound magnesium oxide
   (ii) lithium and nitrogen atoms to give the ionic compound lithium nitride.

[4]

b. Define the term ***lattice enthalpy.*** Which factors govern the magnitude of the lattice enthalpy of an ionic compound?

[2]

c. Explain the following trends in lattice enthalpy:
   (i) $MgO > MgCl_2$
   (ii) $NaCl > RbBr > CsBr$

[4]

d. Using Lewis symbols and Lewis structures diagram the formation of the following molecules from their atoms
   (i) $\underline{P}F_3$ (ii) $H\underline{Br}$ (iii) $H_2\underline{S}$ and (iv) $\underline{C}H_4$

[8]

e. How many lone pairs of electrons are in the underlined atoms in the compounds of d.

[2]

Physical Constants		
Constant	**Symbol**	**Value**
Atomic mass unit	*amu*	1.660554×10^{-27} kg
Avogadro's number	N_A	6.02214×10^{23} mol^{-1}
Bohr radius	a_o	5.292×10^{-11} m
Boltzmann's constant	k	1.38066×10^{-23} J K-1
Charge of an electron	e	1.60218×10^{-19} C
Faraday's constant	F	96,485 C mol^{-1}
Gas constant	R	8.31451 J K^{-1} mol^{-1}
		0.08206 L atm K^{-1} mol^{-1}
Mass of an electron	m_e	9.10939×10^{-31} kg
		5.48580×10^{-4} amu
Mass of a neutron	m_n	1.67493×10^{-27} kg
		1.00866 amu
Mass of a proton	m_p	1.67262×10^{-27} kg
		1.00728 amu
Planck's constant	h	6.62608 x 10-34 J s
Speed of light	c	2.99792458×10^{8} m s^{-1}
1 atm = 760mmHg = 1.0132×10^5 Nm^{-2} = 1.0132×10^5Pa		

THE COPPERBELT UNIVER
SCHOOL OF MATHEMATICS AND NATUR
CHEMISTRY DEPA

The Periodic Table

Key: Atomic Number / Element / Atomic Mass

1	2											3	4	5	6	7	0
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											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											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.37	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 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.21	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)															

†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

THE COPPERBELT UNIVERSITY
SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

CHEMISTRY DEPARTMENT

ANSWER-KEY

TEST 1 - 13th June 2014

COURSE CODE - CH 110 /CH 120/ FO 130

TIME ALLOWED: TWO (02) HOURS

INSTRUCTIONS TO CANDIDATES:

1. *This paper comprises X questions, and is printed on x number of pages. Candidates are expected to attempt ALL questions.*
2. *Each question carries twenty (20) marks.*
3. *Candidates are reminded of the need for the clear presentation in their answers.*
4. *All the parts of a question should be answered strictly in continuation.*

Patrick

Question One

a. Use exponential notation to express the number 385,500 to:

i. one significant figure.

4×10^5 (1 sig. figure) ½

ii. three significant figures.

3.86×10^5 (3 sig. figures) ½

[1]

b. Perform the following mathematical operations, and express each result to the correct number of significant figures.

i. $(6.404 \times 2.91) \div (18.7 - 17.1)$

$6.404 \times 2.91 = 18.6$ (3 sig. figures)

$18.7 - 17.1 = 1.6$ (1 decimal place) ½

Then $18.6 \div 1.6 =$ <u>12 (2 sig figures)</u> ½

ii. $\frac{2.526}{3.1} + \frac{0.470}{0.623} + \frac{80.705}{0.4326}$

$\frac{2.526}{3.1}$ **= 0.81 (2 sig. Figures)**

$\frac{0.470}{0.623}$ **= 0.754 (3 sig. figures)**

$\frac{80.705}{0.4326}$ **= 186.6(4 sig. figures** ½

Then **0.81 + 0.754 + 186.6 = <u>188.2 (1 decimal place)</u>** ½

[2]

c. A star is estimated to have a mass of 2×10^{36}kg. Assuming it to be a sphere of average radius 7.0×10^5km, calculate the average density of the star in units of grams per cubic centimeter.

Convert kg into g: 2×10^{39}g

Convert km into cm: 7.0×10^{10}cm ½

D = mass/volume.

But volume of sphere = $4/3\pi r^3 = 4/3(22 \div 7)(7.0 \times 10^{10}cm)^3 = 1.44 \times 10^{33}cm^3$ ½

So D = $2 \times 10^{39}g \div 1.44 \times 10^{33}cm^3$ = <u>$1 \times 10^6 g/cm^3$</u> 1

d. Diamonds are measured in carats, and 1 carat = 0.200 g. The density of diamond is 3.51 g/cm^3. [2]

i. What is the volume of a 5.0-carat diamond?

D = m÷v So v = m÷D = 5 x 0.200g ÷ 3.51g/cm^3 = 0.28cm^3 **2**

ii. What is the mass in carats of a diamond measuring 2.8 mL?

M= D x V = 3.51g/cm^3 x 2.8ml = 9.828 g

9.828g/0.200g = 49 carats

2

e. In a scientific method, what is the importance of formulating a hypothesis? [4]

(A hypothesis is an intelligent possible explanation of the problem, hence it guides in designing research and/or experiments)

f. Define the terms: [1]

i. **Nuclide = General term applied to each atom represented by $^A_Z X$, where X is the symbol of an element**

ii. **Nucleon = particle in the nucleus (proton or neutron)**

iii. **Mass number = sum of protons and neutrons in the nucleus**

iv. **Isotope = atoms with same atomic number but differing mass number**

g. One isotope of copper is ^{65}Cu. Give the number of its neutrons and protons. [4]

The atomic number of 29 is obtained from the periodic table. Hence 29 protons, and (65 – 29) 36 neutrons

h. What decimal fraction of a second is a pico-second, ps? [2]

10^{-12} sec

[1]

i. The ideal gas equation is given by PV = nRT, where P is pressure in Newton per square area, V is volume, n is the number of moles, T is temperature and R is the gas constant. Show by units analysis that the derived unit of R = Joule. mol^{-1}.K^{-1}

units: P = F/A = N/m^2

V = m^3

n = mol

T = K

So units of R = (N/m^2 . m^3) / mol.K = N.m/mol.K

But N.m = joule

= J.mol^{-1}.K^{-1}

[3]

QUESTION ONE (*Introduction*) **[15 Marks]**

a. Use exponential notation to express the number 385,500 to:
   (i) one significant figure.
   (ii) three significant figures.

(4×10^5 and 3.86×10^5) [1]

b. Perform the following mathematical operations, and express each result to the correct number of significant figures.
   (i) $(6.404 \times 2.91) \div (18.7 - 17.1)$
   (ii) $\frac{2.526}{3.1} + \frac{0.470}{0.623} + \frac{80.705}{0.4326}$

(12 and 188.1) [2]

c. A star is estimated to have a mass of 2×10^{36}kg. Assuming it to be a sphere of average radius 7.0×10^5km, calculate the average density of the star in units of grams per cubic centimeter.

($1 \times 10^6 g/cm^3$) [2]

d. Diamonds are measured in carats, and 1 carat = 0.200 g. The density of diamond is 3.51 g/cm^3.
   (i) What is the volume of a 5.0-carat diamond?
   (ii) What is the mass in carats of a diamond measuring 2.8 mL?

($0.28 cm^3$ and 49 carats) [4]

e. In a scientific method, what is the importance of formulating a hypothesis?
   (A hypothesis is an intelligent possible explanation of the problem, hence it guides in designing research and/or experiments)

[1]

f. Define the terms
   (i) Nuclide (ii) Nucleon (iii) Mass Number (iv) Isotopes

   Nuclide is the general term applied to each atom; represented by the $^{A}_{Z}X$, where X is the symbol of a particular element.

   Nucleon is a particle in an atomic nucleus, either a neutron or proton.

   Mass number is the sum of the number of neutrons and protons in an atomic nucleus.

   Isotopes are atoms of the same element (same atomic number) with different number of neutrons.

g. One isotope of copper is ^{65}Cu. Give the number of its neutrons and protons. [4]

(Mass number (A)=Number of protons (Z) + Number of neutrons (N). A=65 as given in the question; Z=29 as obtained from the periodic table. Therefore N=65-29=36)

[2]

g. What decimal fraction of a second is a pico-second, ps?

(10^{-12} sec) [1]

h. The ideal gas equation is given by PV = nRT, where P is pressure in Newton per square area, V is volume, n is the number of moles, T is temperature and R is the gas constant. Show by units analysis that the derived unit of R = Joule·mol^{-1}·K^{-1}.

[3]

QUESTION TWO (*Atomic Theory*)

[20 Marks]

a. The atomic weight of copper is 63.646 amu. The two naturally occurring isotopes of copper have the following masses: ^{63}Cu, 62.9298 amu; ^{65}Cu, 64.9278 amu. Calculate the percent abundance of ^{65}Cu in nature.

ANSWER: [2.5]

Let the % abundance of ^{65}Cu be x and its mass be A_1

Hence % abundance of ^{63}Cu = 100-x and its mass be A_2

$\sum_{i=1}^{n}$(mass of isotope)(% abundance) = average mass of atom.

Therefore: $A_1 \times \frac{x}{100} + A_2 \times \frac{100-x}{100} = 63.646$ [0.5]

$$A_1 \cdot x + A_2 \cdot (100-x) = 63.646 \times 100$$
$$A_1 \cdot x + A_2 \cdot (100-x) = 6364.6$$
$$64.9278 \cdot x + 62.9298 \cdot (100-x) = 6364.6$$
$$64.9278 \cdot x + 6292.98 - 62.9298 \cdot x = 6364.6$$
$$64.9278 \cdot x - 62.9298 \cdot x = 6364.6 - 6292.98$$
$$1.998 \cdot x = 71.62$$
$$x = 35.84584585$$
$$x = 35.846\ \%.$$

b. State each of the following: [2]

(i) Heisenberg uncertainty principle

(ii) Pauli exclusion principle

(iii) Hund's rule

(iv) Electron affinity
(v) Electronegativity

[2.5]

ANSWER

Heisenberg uncertainty principle is a principle stating that there is a fundamental limitation to how precisely both the position and momentum can be known at a given time. [0.5]

Pauli exclusion principle states that in a given atom no two electrons can have the same set of four quantum numbers. [0.5]

Hund's rule states that the lowest energy in an atom is the one having the maximum number of unpaired electrons allowed by the Pauli exclusion principle in a set of degenerate orbitals, with all unpaired electrons hav~~e~~ing parallel spins. [0.5]

Electron affinity is the energy change associated with the addition of an ~~atom~~ electron to a gaseous atom. [0.5]

Electronegativity is the tendency of atom in an atom to attract shared electrons to itself. [0.5]

In the electronic configuration representation $3d^5$;

(i) What does each of the numbers 3 and 5 represent?

[2]

ANSWER:

3 represents the principal quantum number "n" [1]

5 represents the number of electrons in the subshell. [1]

(ii) Which quantum number is represented by the symbol "d"?

[1]

ANSWER: "d" represents the azimuthal quantum number [1]

Copper is the 29th element in the periodic table of elements, for copper:

(i) Give the ground state electronic configuration,

[2]

ANSWER: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$. [2]

(ii) Draw the orbital diagrams for the electronic configuration in d(i) above

[2]

ANSWER:

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑	↑↓	↑↓	↑↓	↑↓	↑↓
1s	2s	2p	2p	2p	3s	3p	3p	3p	4s	3d	3d	3d	3d	3d

[2]

(iii) Give the set of the four quantum numbers for the 3rd electron in ground state of copper

[1]

ANSWER: 3rd electron the set of the four quantum numbers is (2,0,0,+½) [1]

(iv) Give the set of the four quantum numbers for the 19th electron in ground state of copper.

[1]

ANSWER: 19th electron the set of the four quantum numbers is (4,0,0,+½) [1]

(v) Which electron in the ground state of copper has the following set of the four quantum numbers; (3, 0, 0, -½)

[1]

ANSWER: The electron with the set of four quantum numbers of (3, 0, 0, -½) is the 12th electron. [1]

e. Calculate the;

(i) Energy difference in joules between n=1 and n=5 principal energy levels of a hydrogenic atom.

[2]

ANSWER:

$\Delta E = A\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ [0.5] Where $n_1 = 1$, $n_2 = 5$, and $A = 2.18 \times 10^{-18}$J

$\Delta E = A\left(\frac{1}{1^2} - \frac{1}{5^2}\right)$

$\Delta E = \frac{24}{25}A$

$\Delta E = \frac{24}{25} \times 2.18 \times 10^{-18}$J

$\Delta E = 2.0928 \times 10^{-18}$J

$\Delta E = 2.09 \times 10^{-18}$J [1.5]

(ii) de Broglie wavelength of a boy of mass 10.5 kg experiencing translational motion at 18 km/h.

[3]

ANSWER: de Broglie wavelength is given by the equation

Wavelength $= \frac{h}{mv}$ [1]

where $h = 6.63 \times 10^{-34}$J·s, m = 10.5 kg and v = 18 km/h = 5m/s

Wavelength $= \frac{6.63 \times 10^{-34} \text{J.s}}{10.5 \text{ kg} \times 5 \text{m/s}}$ Note: 1 J = 1 kg·m²/s²

Wavelength $= \frac{6.63 \times 10^{-34} \text{kg·m}^2\text{·s/s}^2}{10.5 \text{ kg} \times 5 \text{ m/s}}$

Wavelength = $1.262857143 \times 10^{-35}$m
Wavelength = 1.3×10^{-35}m
Hence the de Broglie wavelength is 1.3×10^{-35}m [2]