QUESTION 1 (15 MARKS)

a) With respect to the Aufbau, Hund and Pauli exclusion principle, write the electron configuration and orbital diagram of

i. the carbon atom in the gaseous state.
ii. the metal ion, M^{2+} in the ground state. The metal M has the proton number of 29.

(2+2 marks)

b) An atom can be ionised when it is bombarded with light of suitable wavelength. When sodium atoms are bombarded with light of wavelength of 242 nm, they are ionised to form sodium ions. Calculate the ionisation energy of sodium in kJ mol^{-1}.

(3 marks)

c) The relative atomic mass of silicon is 28.09. Naturally occurring silicon consists of three isotopes, silicon−28, silicon−29 and silicon−30. If the isotopic abundance of silicon−29 is 4.7%, what is the isotopic abundance of silicon−28?

(3 marks)

d) 10 mL of a gaseous hydrocarbon C_xH_y combined with 50 mL of oxygen to produce 30 mL of carbon dioxide. Determine the molecular formula of the hydrocarbon (All volumes are measured under the same temperature and pressure)

(5 marks)

QUESTION 2 (15 MARKS)

a) A 1.50 dm^3 sample of a mixture of ethane gas, C_2H_6 and oxygen gas, measured at 25 ºC and 101 kPa, was allowed to react in a bomb calorimeter in which, had a heat capacity of 5.03 kJ/K altogether with its contents. The complete combustion of the ethane gas to carbon dioxide gas and water caused a temperature rise in the calorimeter of 6.18 K. Given that ΔH^o_c (C_2H_6) is -1560 kJ/mol.

i. Define the standard enthalpy of combustion of ethane.
ii. Knowing the ΔH^o_c of ethane, calculate the number of mole of ethane in the mixture.
iii. Calculate the total moles of gases in the calorimeter.

(1+3+2 marks)

b) Butane is a hydrocarbon gas that commonly used for cooking. The standard enthalpy of combustion of butane is -220.1 kJ/mol. 10 g of butane is used to heat 8 L of water. Assuming that no heat is lost to the surroundings, what is the increase in the water's temperature? Given that the specific heat capacity of water is, $s(H_2O)$ = 4.18 J/g.ºC and water density is 1g/L.

(5 marks)

c) Given the following data, determine the enthalpy change for the formation of 40 g of methane, CH_4.

$$C\ (s) + 2\ H_2\ (g) \rightarrow CH_4\ (g)$$

$CH_4\ (g) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (l)$ $\quad \Delta H^o_c = -890.3$ kJ/mol

$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$ $\quad \Delta H^o_f = -393.5$ kJ/mol

$H_2\ (g) + ½\ O_2\ (g) \rightarrow H_2O\ (l)$ $\quad \Delta H^o_f = -285.8$ kJ/mol

(4 marks)

QUESTION 3 (20 MARKS)

a) Consider the following reaction:

$$CH_3Br\,(aq) + OH^-\,(aq) \rightarrow CH_3OH(aq) + Br^-(aq)$$

The rate law for this reaction is first order in CH_3Br and first order in OH^-. When $[CH_3Br]$ is 5.0×10^{-3} M and $[OH^-]$ is 0.120 M, the reaction rate at 303 K is 0.256 M/s.

i. Calculate the rate constant

ii. Determine the unit of the rate constant

(2+1 marks)

b) The gas phase decomposition of NO_2, $2\,NO_2(g) \rightarrow 2\,NO\,(g) + O_2(g)$, is studied at 383 °C, giving the following data:

Time (s)	$[NO_2]$ (M)
0.0	0.100
5.0	0.017
10.0	0.0090
15.0	0.0062
20.0	0.0047

i. Determine the order of the reaction by using the mathematical method.

ii. Calculate the half-life of the reaction.

iii. Do you expect the second half-life of the reaction to have the same value as the first one? Briefly explain your reasoning.

(4+1+2 marks)

c) Nitric oxide (NO) reacts readily with chlorine gas as follows:

$$2\,NO(g) + Cl_2\,(g) \rightarrow 2\,NOCl(g)$$

Given pressures of nitric oxide (NO) is 0.16 atm, chlorine (Cl_2) is 0.23 atm and NOCl is 0.56 atm.

i. Determine the equilibrium constant, K_p, of the reaction.

ii. At 43 °C temperature, calculate the K_c of the reaction.

iii. Determine the K_c for the reaction $5\,NOCl\,(g) \rightarrow 5\,NO\,(g) + 5/2\,Cl_2\,(g)$

(2+2+2 marks)

d) Aurumn (III) chloride, ($AuCl_3$), has a solubility of 54 g/100 mL of water. Determine the solubility-product constant, K_{sp}, of $AuCl_3$ in water.

(4 marks)

QUESTION 4 (15 MARKS)

a) When saltdissolves, it can form either acidic or basic salt solutions. Calcium chloride, $CaCl_2$ is a salt that is used to develop viscosity in polymers, food additives and preservatives, surfactants, and as a pH control in chemicals. On the other hand, sodium amide, $NaNH_2$ serves as a catalyst and a nucleophilic reagent in the industrial production of indigo dye.

i. The aqueous salt solution of $CaCl_2$is neutral. Explain this statement using the salt dissociation equation in water.

ii. The aqueous salt solution of $NaNH_2$is basic. Explain this statement using the salt dissociation equation in water.

(3+3 marks)

b) During Christmas, Santa Claus found a bottle of used vinegar in his kitchen. Its chemical formula is CH_3COOH, also known as acetic acid. He wants to make a Caesar salad for his reindeer. In order to do that, you are requested to help Santa Claus to find the pH of the acetic acid in the 0.020 M solution. Given Ka = 1.76×10^{-5}.

(5 marks)

c) Buffer solutions are used by the human body to maintain a constant pH for biochemical processes such as enzyme activity. In addition, buffer is used in baby shampoo and soap to maintain the pH, thereby preventing rashes on the baby. Given an ethanoic acid, CH_3COOH with Ka = 1.85×10^{-5}.

i. Calculate the pH of a buffer solution containing 0.150 mol/L ethanoic acid and 0.150 mol/L sodium ethanoate using the Henderson-Hasselbalch equation.

ii. Give the proportion (ratio) for $[CH_3COO^-]$: $[CH_3COOH]$ with the same concentration that we should mix to produce a buffer solution of pH 5.00.

(1+3 marks)

QUESTION 5 (20 MARKS)

a) Given the redox reaction equation below:

$$MnO_4^- (aq) + Zn (s) \rightarrow MnO_2 (s) + Zn^{2+} (aq)$$

i. Complete and balance the above equation in basic solution.
ii. Calculate the standard potential produced from the above redox reaction.
iii. Write the Q_c expression for the above reaction

(5+2+1 marks)

b) Consider a concentration cell (voltaic cell) at temperature of 25°C. The setup consists of copper electrodes on both sides. One side is filled with 300 mL of 0.5 M copper sulfate, $CuSO_4$, solution and the other side is 300 mL of 2.1 M $CuSO_4$ solution.

i. Identify which concentration of $CuSO_4$ should be on cathode and anode.
ii. Calculate the voltage produced by the cell.

(1+4 marks)

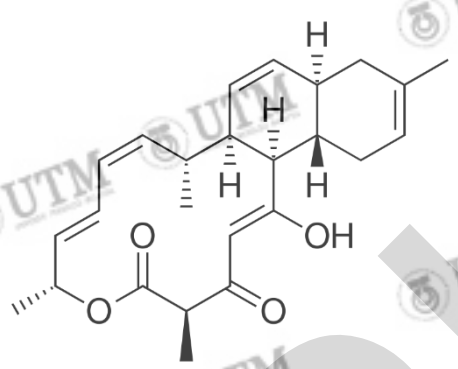
c) Consider 0.2 M of cobalt chloride, $CoCl_2$, in an electrolytic cell with graphite electrodes being used on both sides.

i. Write all the possible chemical equations that may occur on both anode and cathode.
ii. Based on your answer in c(i), identify the major product that will be formed at the anode and cathode.
iii. If 2.2 A of current is applied on the cell for 30 minutes, calculate the mass of product formed at the cathode.

(2+2+3 marks)

QUESTION 6 (15 MARKS)

a) Anthracimycin is a new potential drug, derived from marine microorganism discovered in 2013. It is effective against anthrax and various other Gram-positive bacteria. Redraw the figure given below in your answer sheet and circle **FOUR** functional groups that you can find in the anthracimycin molecule.



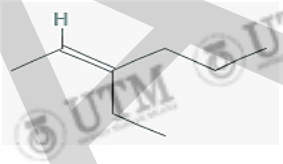
(4 marks)

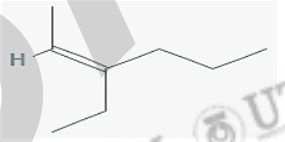
b) Draw the structural formula for the following molecules :

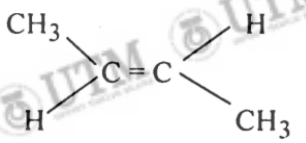
i. 1,2-dimethylcyclobutane
ii. 2,2-dimethylpropane
iii. 1,4-hexadiene
iv. toluene
v. ortho-hydroxybenzoic acid
vi. methylcyclopropane
vii. propanal

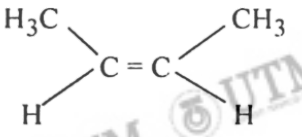
(7 marks)

c) Write the IUPAC name for the given molecules below :

i. 

ii. 

iii. 

iv. 

(4 marks)

LIST OF SELECTED CONSTANT VALUES

Ionisation constant for water at 25°C	K_w	=	1.00×10^{-14} mol^2 dm^{-6}
Molar volume of gases	V_m	=	22.4 dm^3 mol^{-1} at STP
		=	24 dm^3 mol^{-1} at RT
Speed of light in a vacuum	c	=	3.0×10^8 m s^{-1}
Avogadro's number	N_A	=	6.02×10^{23} mol^{-1}
Faraday constant	F	=	9.65×10^4 C mol^{-1}
Planck constant	h	=	6.6256×10^{-34} J s
Reduced Planck constant	$\hbar$	=	1.054×10^{-34} J s
Rydberg constant	R_H	=	1.097×10^7 m^{-1}
		=	2.18×10^{-14} J
Molar of gases constant	R	=	8.314 J K^{-1} mol^{-1}
		=	8.314 L kPa K^{-1} mol^{-1}
		=	0.08206 L atm mol^{-1} K^{-1}
Boltzmann constant	k	=	1.3807×10^{-27} J K^{-1}
Mass of proton	Mp	=	1.672×10^{-27} kg
Electronic Bohr magneton	µB	=	9.2741×10^{-27} J T^{-1}
Nuclear Bohr magneton	β_N	=	5.05×10^{-27} J T^{-1}
Vapour pressure of water	P_{water}	=	23.8 torr
Electron charge	e-	=	1.602×10^{-19} C

UNIT AND CONVERSION FACTOR

Energy	1 J	= 1 kg m^2 s^{-2} = 1 N m = 10^7 erg
	1 calorie	= 4.184 Joule
	1 eV	= 1.602×10^{-19} J
	1 amu	= 1.66×10^{-27} kg
Pressure	1 atm	= 760 mm Hg = 760 torr = 101.325 kPa = 101325 N m^{-2}

SELECTED FORMULA

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad \pi = MRT \qquad 4r = a\sqrt{2}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad rate = \sqrt{\frac{1}{density}}$$

THE PERIODIC TABLE

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
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** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.1	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
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** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.29
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	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	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac^** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	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
^	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	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)	103 **Lr** (260)

STANDARD REDUCTION POTENTIAL ELECTROCHEMICAL SERIES

Half-Reaction	E (Volts)
$K^+ + e^- \rightleftharpoons K$	-2.924
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	-2.900
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	-2.760
$Na^+ + e^- \rightleftharpoons Na$	-2.712
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	-2.375
$H_2 + 2e^- \rightleftharpoons 2\ H^-$	-2.230
$Al^{3+} + 3e^- \rightleftharpoons Al$	-1.706
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	-1.040
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	-0.763
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	-0.740
$S + 2e^- \rightleftharpoons S^{2-}$	-0.508
$2CO_2 + 2H^+ + 2e^- \rightleftharpoons H_2C_2O_4$	-0.490
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	-0.410
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	-0.409
$Co^{2+} + 2e^- \rightleftharpoons Co$	-0.280
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	-0.230
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	-0.136
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	-0.126
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	-0.036
$2H^+ + 2e^- \rightleftharpoons H_2$	0.000
$S_4O_6^{2-} + 2e^- \rightleftharpoons 2\ S_2O_3^{2-}$	0.089
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	0.150
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	0.158
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	0.340
$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	0.401
$Cu^+ + e^- \rightleftharpoons Cu$	0.522
$I_3^- + 2e^- \rightleftharpoons 3\ I^-$	0.534
$MnO_4^- + 2H_2O + 3e^- \rightleftharpoons MnO_2 + 4OH^-$	0.588
$O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	0.682
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	0.770
$Hg_2^{2+} + 2e^- \rightleftharpoons Hg$	0.796
$Cl_2 + 2e^- \rightleftharpoons 2Cl$	1.360