UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2024 SEMESTER

COURSE : YBB2053 - ORGANOTRANSITION METAL CHEMISTRY

DATE : 6 APRIL 2024 (SATURDAY)

TIME : 9:00 AM - 12:00 NOON (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SEVEN (7)** pages in this Question Booklet including the cover page .

ii. **DOUBLE-SIDED** Question Booklet.

1. $K_3[Fe(SCN)_6]$ has been used to synthesize potassium-ion battery cathode material.

a. Determine the International Union of Pure and Applied Chemistry (IUPAC) nomenclature of $K_3[Fe(SCN)_6]$ complex.

[2 marks]

b. Draw the molecular orbital diagram of $K_3[Fe(SCN)_6]$ complex with complete labelling.

[10 marks]

c. Determine the crystal field stabilization energy (CFSE) of $K_3[Fe(SCN)_6]$ complex.

[2 marks]

d. Determine the magnetic moment of $K_3[Fe(SCN)_6]$ complex.

[2 marks]

e. Sketch the orbital interaction(s) between the ligand and the metal centre in $K_3[Fe(SCN)_6]$ complex to represent the characteristics of the ligand in the complex.

[4 marks]

2. Crystal field theory is a model that describes the electronic structure of transition metal compounds.

a. Using crystal field theory, discuss the splitting of *d* orbitals in octahedral complex. Support your discussion with drawings.

[10 marks]

b. Draw the arrangement of electrons in *d* orbitals of $[CuF_6]^{5-}$.

[3 marks]

c. It has been observed that $[CuF_6]^{4-}$ will undergo Jahn-Teller Distortion. Draw the splitting of the *d* orbitals in this complex.

[7 marks]

3. The $[Pt(NH_3)_4]^{2+}$ complex ion is reacted with one equivalent mole of Cl^- to form complex **X**. Then, complex **X** is reacted with another mole of Cl^- to produce complex **Y**.

a. Using curved arrows, propose an associative mechanism for the formation of complex **X**.

[4 marks]

b. Determine the rate of reaction in **part (a)** when the concentration of $[Pt(NH_3)_4]^{2+}$ and Cl^- are doubled. Justify your answer.

[3 marks]

c. Determine the rate of reaction if the $[Pt(NH_3)_4]^{2+}$ complex ion in **part (a)** is replaced by $[Ni(NH_3)_4]^{2+}$.

[3 marks]

d. Determine the rate of reaction if the $[Pt(NH_3)_4]^{2+}$ complex ion in **part (a)** is replaced by $[Pt(NH_3)_4]^{4+}$.

[3 marks]

e. Complex **X** undergoes a dissociative mechanism to form complex Y. Draw a mechanism for the transformation of complex **X** to complex **Y** using curved arrows.

[3 marks]

f. Determine the rate of reaction in **part (e)** when the concentrations of complex **X** and ligand Cl^- are doubled. Justify your answer.

[4 marks]

4. Polypropylene (PP) is a thermoplastic polymer widely used for fabricated parts and components due to its excellent chemical and impact resistance. In a typical polymerization of propylene (C_3H_7) monomers to PP, dimethylzirconocene, $(\eta^5\text{-}C_5H_5)_2Zr(CH_3)_2$ is used as a catalyst.

a. Draw the structure of dimethylzirconocene.

[2 marks]

b. Propose a catalytic cycle for polymerization of 2 moles of propylene (C_3H_7) monomer.

[10 marks]

c. Calculate the number of electrons around the central metal ion in each step of the mechanisms as shown in **part (b).**

[8 marks]

5. Hydroformylation of olefin is an important industrial process where olefin reacts with syngas (H_2 and CO) to produce linear and branched aldehydes. $[Fe(CO)_3(PPh_3)_2]$ is one of the catalysts commonly used for hydroformylation reaction.

a. Draw a catalytic cycle for the hydroformylation of 1-hexene (C_6H_{12}) to branched aldehyde.

[10 marks]

b. Identify the type of reaction in each step of the mechanism in **part (a)**.

[8 marks]

c. Name the aldehyde produced from **part (a)**.

[2 marks]

– END OF PAPER –

APPENDIX I (PERIODIC TABLE)

B = Solids   Hg = Liquids   Kr = Gases   Pm = Not found in nature

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.87	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Uut (277)	114 Uuq (277)	115 Uup (277)	116 Uuh (277)		118 Uuo (277)
			57 La 138.9055	58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	
			89 Ac 232.0381	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	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)	