UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED CHEMISTRY

NATIONAL DIPLOMA: ANALYTICAL CHEMISTRY

MODULE: CET3APC
POLYMER CHEMISTRY 3

CAMPUS **DFC**

JUNE EXAMINATION

Name (Optional):	
Student Number:	
Signature:	

DATE: 5th June 2018
EXAMINER: Prof PG Ndungu (UJ)
INTERNAL MODERATOR: Dr M Mamo (UJ)
EXTERNAL MODERATOR: Dr SP Hlangothi (NMMU)

SESSION: 12:30 – 15:30

DURATION: 3 HOURS

Question	1	2	3	4	5	6	7	8	9	10	TOTAL
Marks	5	12	2	23	16	10	6	10	4	12	100
Examiner											
Moderator											

Percentage (%) = _____

NUMBER OF PAGES: 1 Cover PAGE + 15 PAGES
PERIODIC TABLE

INSTRUCTIONS:

- ANSWER ALL QUESTIONS IN PEN IN THE SPACES PROVIDED
- CALCULATORS ARE PERMITTED, BUT EACH STEP IN ANY CALCULATION MUST BE SHOWN.
- THE BLANK SIDE OF THE PAGES MAY BE USED FOR EXTRA SPACE OR FOR ROUGH WORK (INDICATE CLEARLY)

REQUIREMENTS: GRAPH PAPER

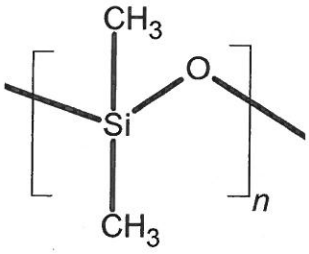
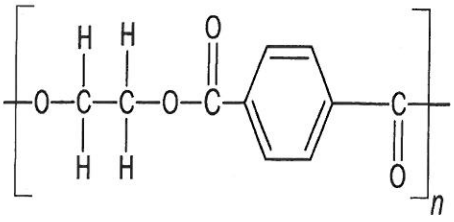
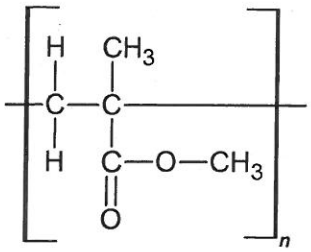
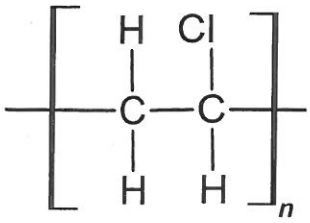
QUESTON 1

From a historical perspective, would you classify the current age as the Stone Age, Bronze Age, Iron Age, or Plastic Age, and provide a reasonable explanation for your answer.

[5]

QUESTON 2

Complete the following table:

Polymer Structure	Polymer Name	M_n	DP
		120 000	
		200 000	
		98 565	
		240 000	

[12]

QUESTON 3

Provide simple illustrations that show the differences between homopolymer, random copolymer, alternating copolymer, and a block copolymer.

[2]

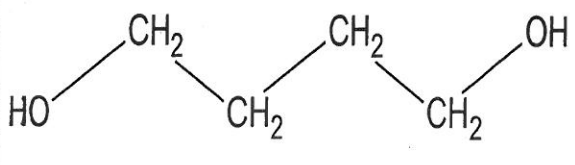
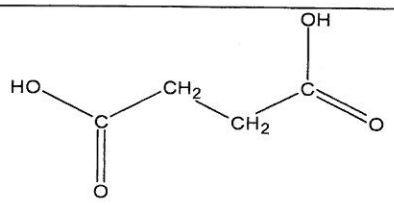
QUESTON 4

a. Provide a short definition of step growth polymerization.

(2)

b. Polybutylene succinate is a biodegradable polymer that can be synthesised from succinic acid and 1,4-butanediol. What by-product would you expect from the polymerisation reaction?

(1)

	
1,4-butanediol	succinic acid

c. Provide a plausible mechanism for the formation of the dimer during the synthesis of polybutylene succinate from succinic acid and 1,4-butanediol, and provide an overall equation for the polymerisation.

(8)

d. Nonjabulo is setting up a company in Limpopo to synthesize polybutylene succinate shopping bags for a local retailer. To save costs, Nonjabulo decides to make the polymer with a DP of 1200, and without a catalyst at 200 °C using an initial concentration of 7.5 M succinic acid. If the rate of polymerisation for the reaction is 5.6 x 10^{-3} L mol^{-1} s^{-1}, how long will it take to make the polymer? Provide your answer in number of days

(6)

e. As an intern at Nonjabulo's company, what would you recommend they add to the reaction system to decrease the time for the synthesis of the polymer?

(1)

f. The additive added to the polymerisation reaction changes the rate to 1.1×10^{-2} L mol^{-1} s^{-1}, using 3.0 M of succinic acid, a target DP = 800, and a temperature of 200 °C, how long will the reaction take? Provide your answer in number of hours.

(4)

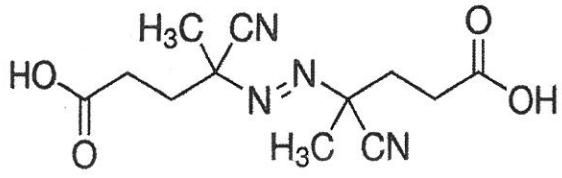
g. Why is the reaction carried out at 200 °C?

(1)

[23]

QUESTON 5

The initiator, 4,4'-Azobis(4-cyanovaleric acid), can be used with the monomer styrene (C_8H_8) to produce polystyrene The reaction is very exothermic.



4,4'-Azobis(4-cyanovaleric acid)

a. Is the initiator 4,4'-Azobis(4-cyanovaleric acid) a cationic, anionic, or radical initiator?

(1)

b. Approximately how much initiator is needed to produce 100 kg of the polymer with a DP of 1400?

(6)

c. You have won a young entrepreneurship award to start a polymer processing factory that produces polystyrene for export across the African continent. Your first production run at your factory produced a polymer with M_n = 330 000 g/mol, using ethylbenzene as a chain transfer agent (chain transfer agent/monomer ratio = 0.365). If the chain transfer constant was 0.00067, calculate DP and M_n for the reaction with no chain transfer agent.

(5)

d. The product produced in your factory is atactic; however, your sales engineers has suggested that isotactic polystyrene would be much more profitable if sold on the open market. Provide an illustration that shows the differences between atactic and isotactic polystyrene, and suggest a method to produce the isotactic form.

(4)

[16]

QUESTON 6

a. Define emulsion polymerisation

(2)

b. List the advantages and disadvantages of emulsion polymerisation.

(8)

[10]

QUESTON 7

How are solubility parameters useful in an industrial setting?

[6]

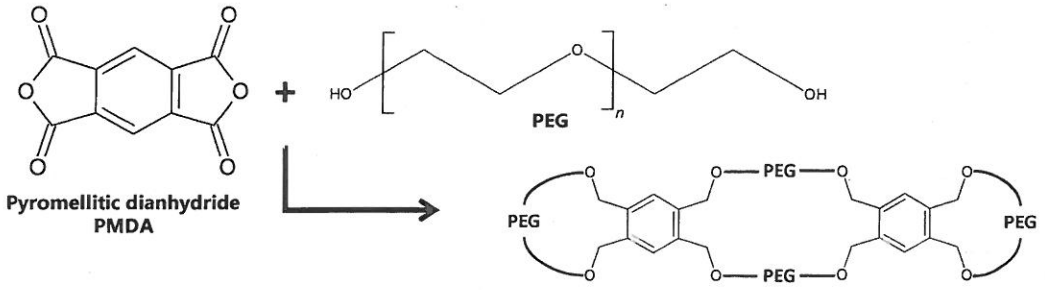
QUESTON 8

The following questions concern end group analysis of polymers.

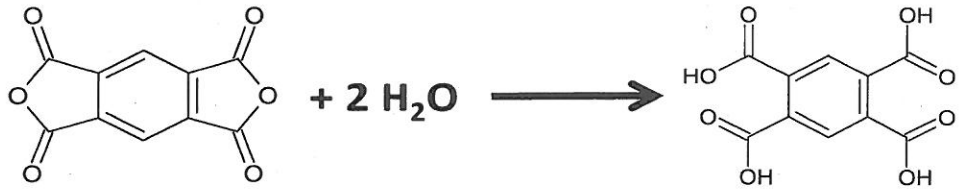
a. What is end group analysis when determining polymer molecular weight?

(4)

b. The molecular weight of polyethylene glycol (PEG) can be determined using end group analysis using excess pyromellitic diahydride. The un-balanced equation is as follows:



The excess unreacted pyromellitic diahydride is then reacted with water to form the acidic form (balanced equation):



How many moles of NaOH will react with 1 mole of the acidic form of the diahydride?

(1)

c. If 55.15 mL of 0.25 M NaOH are used to titrate the acidic form of PMDA, how many moles of PMDA were present?

(1)

d. If the initial mass of PMDA was 0.8555 g, how moles of PEG were used?

(2)

e. Based on the moles of PMDA (4 mol PMDA: 1 mol PEG) used calculate the average molecular weight of PEG given that the initial mass of PEG was 0.1515 g

(2)

[10]

QUESTON 9

Provide a brief overview of plasticisers and how they affect polymer properties.

[4]

QUESTON 10

Provide a diagram and a brief explanation on the process of compression moulding, two examples of polymers used and types of products produced using this process.

[12]

TOTAL 100 MARKS

END OF EXAM PAPER

DATA PAGE

$\overline{X_n} = \frac{1}{1-P}$	$\overline{DP} = 1 + K^{1}/_{2}$	$p = \frac{K^{1/2}}{1+K^{1/2}}$	$r = \frac{K_{11}}{K_{12}}$
$\overline{DP} = \frac{\overline{M_n}}{m}$	$[H_2O] = \frac{K[M]_0}{\overline{X_n}(\overline{X_n}-1)}$	$\frac{1}{DP} = \frac{1}{DP_0} + C\frac{[TH]}{[M]}$	$r = \frac{K_{22}}{K_{21}}$
$\overline{DP_n} = 2\nu$	$\bar{M}_n = M_0\overline{DP_n}$	$\eta_{rel} = \frac{\eta}{\eta_0} = \frac{t}{t_0}$	$\overline{DP_n} = \nu$
$\overline{DP} = \frac{\overline{M_n}}{m}$	$\bar{M}_n = M_0\overline{DP_n}$	$\left(\frac{\pi}{C}\right)_{c=0} = \frac{RT}{M_n} + A_2C$	$\eta_{sp} = \frac{\eta-\eta_0}{\eta_0}$
$\overline{M_w} = \sum M_i W_i$	$\nu = \frac{K_p^2[M]^2}{2K_tR_p}$	$R_{pol} = \left[K_p\left(\frac{fK_d}{K_t}\right)^{1/2}[M][I]_0^{1/2}\right]e^{-K_dt/2}$	$\eta_{red} = \frac{t-t_0}{t_0C}$
$\overline{M_n} = \sum M_i X_i$	$R_i = 2fK_d[I]$	$R_t = 2K_t[M\bullet]^2$	$\eta_{inh} = \frac{\ln\eta_{rel}}{C}$
$k_t = A_te^{-E_t/RT}$	$k_p = A_pe^{-E_p/RT}$	$k_d = A_de^{-E_d/RT}$	$[\eta] = KM_V^{\alpha}$
$C = \frac{K_{tr}}{K_p}$	$[M\bullet] = \left(\frac{fK_d[I]}{K_t}\right)^{1/2}$	$[COOH]_0kt = \frac{1}{(1-p)} - 1$	$\overline{DP} = \frac{1}{1-P}$
$PDI = \frac{M_W}{M_n}$	$\overline{DP} = \frac{1+r}{r+1-2rp}$	$\frac{1}{(1-p)^2} = 2k[COOH]_0^2t + 1$	$r_i = 2K_d[I]$

Some Useful Constants:

N_A = 6.022 x 10^{23} mol^{-1}

R = 8.3143 J K^{-1} mol^{-1}

R = 0.0820574 dm^3 atm K^{-1} mol^{-1}

R = 0.0831447 dm^3 bar K^{-1} mol^{-1}

R = 8.314462 m^3 Pa K^{-1} mol^{-1}

1 electron volt = 1.60217646 × 10^{-19} joules

F = 96485.3399 C mol^{-1}

Periodic Table of the Elements

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]