UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

KAT 341 – Pollution And Environmental Chemistry
[Kimia Pencemaran Dan Alam Sekitar]

Duration : 3 hour
[Masa : 3 jam]

Please check that this examination paper consists of **TWENTY ONE** printed pages before you begin the examination.

Instruction:-

Answer **FIVE** (5) questions only. Answer **THREE** questions from section A and **TWO** questions from section B.

Answer each question on a new page.

You may answer either in Bahasa Malaysia or in English.

If a candidate answers more than five questions, only the answers to the first five questions in the answer sheet will be graded.

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Section A

1. Fate and transport of chemicals within the aquatic environment will depend on their physical and chemical properties and characteristics of the receiving water. Some of the chemical and physical properties associated with the fate and transport of these chemicals are given in the table below

Properties	Water solubility	Octanol-water partition coefficient	Hydrolysis half-life	Soil sorption
Symbols	WS	K_{OW}	$Ht_{1/2}$	K_{OC}

(a) What is likely and unlikely to happen to a chemical in the aquatic environment if that chemical has (i) a high WS (ii) low K_{OW} and (iii) high K_{OC} ?

(9 marks)

(b) Trichloroethylene has the following physical and chemical properties. Provide its possible fate and transport within the aquatic environment that is most likely to occur.

Trikloroetilena CAS No : 79-01-6 EC No: 201-167-4	WS (25 °C)	1,100 mg L^{-1}
	K_{OW}	~ 260
	K_{OC}	~ 160
	D liquid	> 1.464
	P $t_{1/2}$	~ 1 month
	S $t_{1/2}$	Month to years
	VP (25 °C)	9.2 x 10^3 Pascals

(5 marks)

(c) One of the possible fate of a persistent pollutant is bioaccumulation and biomagnification. Define these two terms.

(6 marks)

2. (a) Differentiate between water quality criteria and water quality standards. Explain why often it could be inappropriate to adopt water quality criteria directly in a pollution control program.

(6 marks)

(b) The following water quality parameters were measured for the nutrient concentrations in a lake.

Orthophosphate, PO_4^{3-}	10 $\mu g\ L^{-1}$
Total Phosphorous (Dissolved)	15 $\mu g\ L^{-1}$
NO_3^- -N	15 $\mu g\ L^{-1}$
NH_4^+-N	10 $\mu g\ L^{-1}$

i) What is the likely limiting nutrient for algal growth in this lake based on the ratio of the two nutrients?

ii) Discuss the implications of having total P content of the lake increased to greater than 0.5 mg L^{-1} due to sudden pollution of the lake.

(14 marks)

3. (a) One of the impacts of chelating agents or ligands in the aquatic environment is to increase the solubility and mobility of heavy metals. This problem is due to the increased dissolution of $PbCO_3(s)$. If a solution containing 25 mgL^{-1} Na_3NTA (MW = 257g $mole^{-1}$) is equilibrated with $PbCO_3(s)$, and is then measured to have a pH of 8.5 and $[HCO_3^-]$ of 1.76 x 10^{-3} M, what is the equilibrium ratio of $[Pb(NTA)^-]/[HNTA^{2-}]$? Useful equations are given below.

$$PbCO_3\ (s) \rightleftharpoons Pb^{2+} + CO_3^{2-} \quad k_{sp} = 1.48 \times 10^{-13}$$

$$Pb^{2+} + NTA^{3-} \rightleftharpoons Pb\ (NTA^-)\ k_f = 2.45 \times 10^{11}$$

$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+ \quad ka_1 = 4.45 \times 10^{-7}$$

$$ka_2 = 4.69 \times 10^{-11}$$

(6 marks)

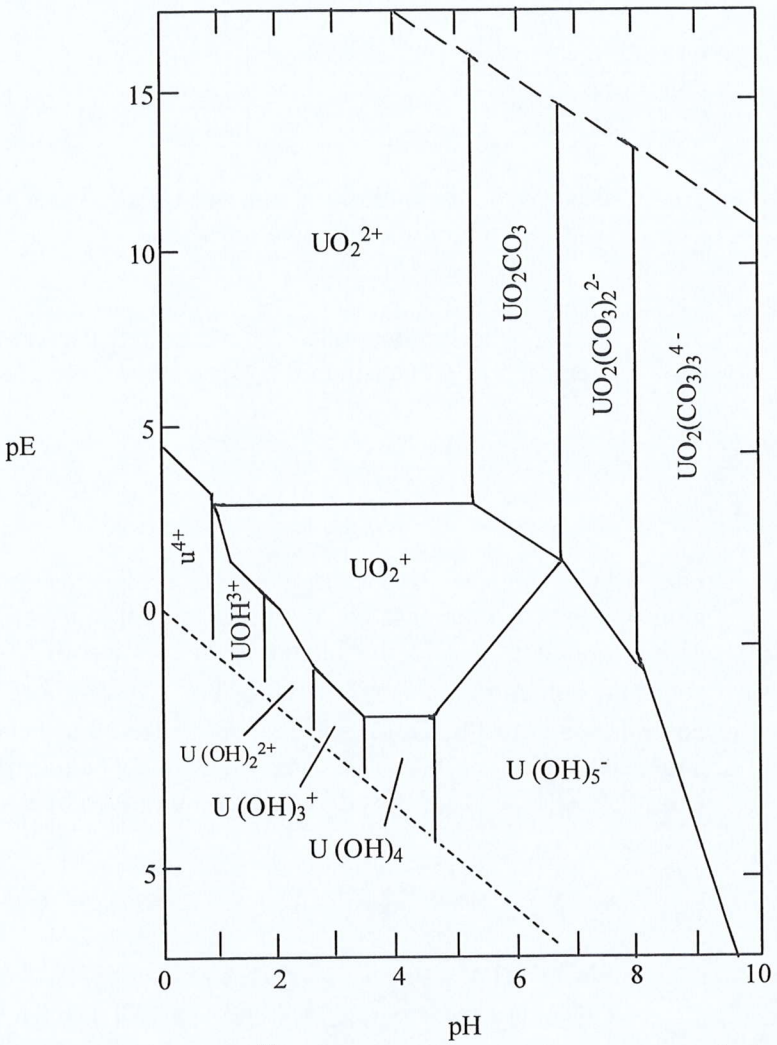
(b) Use the pE-pH diagram below and based on your understanding of methanogenic environments (anaerobic conditions) answer the following questions:

(a) What form of uranium do you predict to dominate in a methane producing environment at pH 6.5.

(b) What form of uranium do you expect to dominate in oxic waters at pH 7.0 ?

(c) Calculate the pE for the two environments in (i) and (ii) above.

(8 marks)



(c) Explain how Hg^{2+} ion is transformed into monomethylmercury and why this organic mercury is far more toxic and can be bioaccumulated as compared to its original Hg^{2+} ion.

(6 marks)

4. (a) A biochemical oxygen demand (BOD) test is run using 100 mL of treated wastewater mixed with 200 mL of pure water. The initial DO of the mixture is 9.0 mg L. After 5 days, the dissolved oxygen (DO) is 4.0 mgL^{-1}. After a long period of time, the DO is 2.0 mgL^{-1} and no longer seems to be decreasing. Asssume that nitrification has been inhibited so that the only BOD being measured is carbonaceous.

i) What is the 5-day BOD of the wastewater (mg L^{-1})?
ii) Estimate the ultimate carbonaceous BOD (mg L^{-1}).

(5 marks)

(b) A city of 200,000 people deposits 1.048 cubic meter per second of sewage having a BOD_U of 28.0 mg/L and DO concentration of 1.8 mgL^{-1} into a river that has a flow rate of 7.079 cubic meter per second and velocity of 0.366 meter persecond. Just upstream of the waste discharge point, the river has a BOD of 3.6 mg L^{-1} and a DO of 7.6 mg/L. The saturation value of DO is 8.5 mg/L. The deoxygenation rate coefficient (k_1) is 0.60 d^{-1} and the re-aeration coefficient (k_2) is 0.76 d^{-1}. Determine the minimum DO concentration and the distance from the discharge point where the minimum value will occur. Plot a graph of DO concentration versus time and indicate time of the minimum DO value and the time when the returns to its "natural" DO concentration of 7.6 mg/L.

(15 marks)

Section B

5. (a) It is estimated that there is 4800 mL of blood in the body. Based on the concentration of O_2 that we breathe, there are 20 mL O_2 per 100 mL blood. We breathe air at the rate of 4.2 liter per minute and the atmospheric concentration of CO is 100 ppm.

i) Convert the given concentration of CO from ppm into $\mu g\ m^{-3}$.
ii) Find the time (in minutes) for blood to become 7 % saturated with CO if the blood is initially 0% saturated with CO.

(10 marks)

(b) In the atmosphere, NO reacts with O_3 to produce NO_2 and O_2. Nitric oxide also reacts with the hydroperoxyl (HO_2·) radical to produce NO_2 and the hyroxyl radical OH· In turn, NO_2 is photolyzed rapidly to produce NO and atomic oxygen. The atomic oxygen quickly combines with O_2 (when aided by an M) to produce O_3. Write balanced chemical equations to represent these four chemical reactions.

(4 marks)

(c) Some clouds containing NO_2 moved towards a region known to contain high concentration of hydrocarbons originating from industrial sources. If that region also received high solar radiation , what would be the impact of the pollution on the environment of that region ? Clarify and justify your answer.

(6 marks)

6. (a) Coal fired electrical generating power plants emits SO_2 gas from the oxidation of S found in coal. This SO_2 gas has been proven to cause acid rain. Formation of sulfuric acid is said to occur via oxidation of SO_2 to sulfuric acid in both gas and aqueous phases. Provides the mechanisms involved in the oxidation proces of SO_2 in both phases.

(8 marks)

(b) Discuss the role of polar stratospheric cloud in the formation of ozone hole in the south pole. Provide relevant chemical equations to clarify your points.

(12 marks)

7. (a) Using appropriate diagrams and equations, provide explanation for the following phenomena in air pollution meteorology:

i) Superadiabatic lapse rate is normally associated with highly instable atmosphere.

ii) Radiation inversion normally occurs at the beginning of night time.

(10 marks)

(b) On an overcast day with a class C stability, the wind vwelocity at 10 m is 4 m s^{-1}. The emission rate of NO is 50 g s^{-1} from a stack having an effective height of 100 m.

i) Estimate the centre line, ground level concentration 20 km downwind from the stack in microgram per cubic meter.

ii) Estimate the ground level concentration 20 km dowhnwind and 900 m from the stack centre line in microgram per cubic meter. Use rural conditions.

(10 marks)

APPENDIX

1. Dilution table for BOD analysis

Direct Measurment		Premixing (Volume of Wastewater to total volume)	
Wastewater (mL)	**BOD range (mg L^{-1})**	**Percent Mixing**	**BOD range (mg L^{-1})**
0.20	3000 – 10,500	0.10	2000 – 7000
0.50	1200 – 4200	0.20	1000 – 3500
1.0	600 – 2100	0.50	400 – 1400
2.0	300 – 1050	1.0	200 – 700
5.0	120 – 420	2.0	100 – 350
10.0	6 – 210	5.0	40 – 140
20.0	30 – 105	10.0	20- 70
50.0	12 – 42	20.0	10 – 35
100	6 – 21	50.0	4 – 14

2. A table for saturated DO values for water of different temperatured

Temp (°C)	DO (mg L^{-1})
18	9.5
19	9.4
20	9.2
21	9.0
22	8.8
23	8.7
24	8.5
25	8.4
26	8.2
27	8.1
28	7.9
29	7.8
30	7.6

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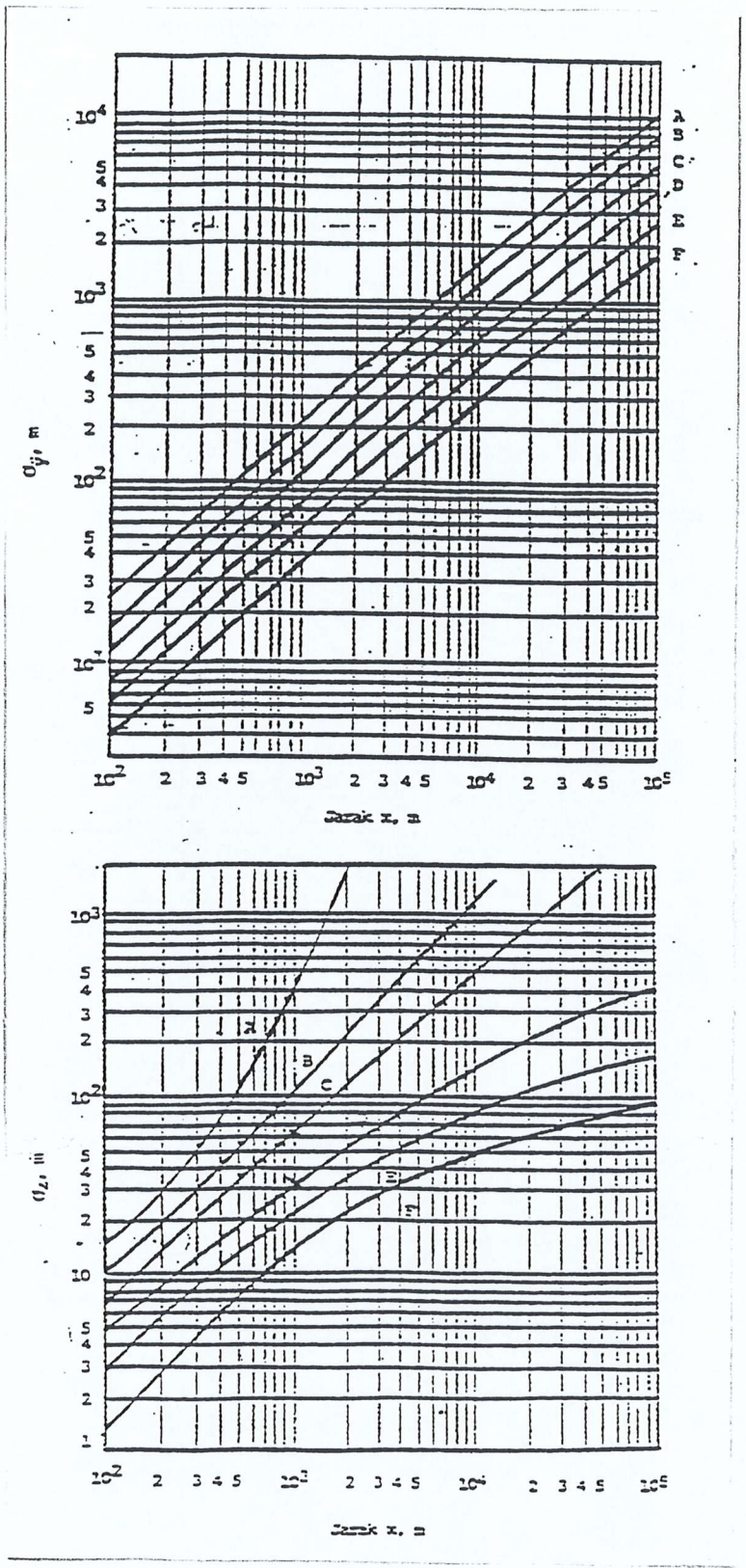
Plots Pasquill - Gifford



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A table of values for σ_Z coefficients.

Atmospheric stability classes	Distance downwind (meter) $100 < x \leq 500$		Distance downwind (meter) $500 < x \leq 5000$		Distance downwind (meter) $5000 < x$	
	a	b	a	b	a	b
A = 1	.0383	.1281	.0002539	2.089	.0002539	2.089
B = 2	.1393	.9467	.04936	1.114	.04936	1.114
C = 3	.1120	.9100	.1014	.926	.1154	.9109
DD = 4	.0856	.8650	.2591	.6869	.7368	.5642
DN = 5	.0818	.8155	.2527	.6341	1.297	.4421
E = 6	.1094	.7657	.2452	.6358	.9204	.4805
F = 7	.05645	.8050	.1930	.6072	1.505	.3662

A table for values of σ_Y coefficients.

Atmospheric stability classes	Distance downwind (meter) $x < 10{,}000$		Distance downwind (meter) $x \geq 10{,}000$	
	a	b	c	d
A = 1	.495	.873	.606	.851
B = 2	.310	.897	.523	.840
C = 3	.197	.908	.285	.867
DD = 4	.122	.916	.193	.865
DN = 5	.122	.916	.193	.865
E = 6	.0934	.912	.141	.868
F = 7	.0625	.911	.0800	.884

Relative atomic mass (RAM)

H = 1; C = 12; N = 14; O = 16; P = 31

S= 32 and Fe = 55.8

Bahagian A

1. Ketentuan dan pengangkutan bahan kimia dalam persekitaran akuatik akan bergantung kepada sifat-sifat kimia dan fizik mereka dan juga ciri-ciri air yang menerimanya. Sebahagian daripada sifat-sifat kimia dan fizik yang dikaitkan dengan ketentuan dan pengangkutan bahan-bahan kimia ini diberikan di dalam jadual dibawah.

Sifat	Keterlarutan Air	Pekali sekatan Oktanol-Air	Masa Separa Hayat Hidrolisis	Erapan Tanah
Simbol	WS	K_{OW}	$Ht_{1/2}$	K_{OC}

(a) Apakah yang berkemungkinan dan juga yang tidak mungkin berlaku ke atas sesuatu bahan kimia dalam persekitaran akuatik sekiranya bahan kimia tersebut mempunyai i) WS yang tinggi dan ii) K_{OW} yang rendah

(9 markah)

(b) Trikloroetilena mempunyai sifat-sifat fizik dan kimia berikut. Berikan ketentuan dan pengangkutan yang paling berkemungkinan berlaku ke atasnya dalam persekitaran akuatik.

Trikloroetilena CAS No : 79-01-6 EC No: 201-167-4	WS (25 °C)	1,100 mg L^{-1}
	K_{OW}	~ 260
	K_{OC}	~ 160
	D liquid	> 1.464
	P $t_{1/2}$	~ 1 month
	S $t_{1/2}$	Month to years
	VP (25 °C)	9.2 x 10^3 Pascals

(5 markah)

(c) Dua daripada ketentuan yang mungkin berlaku ke atas bahan pencemar tegar ialah pengumpulan biologi dan magnifikasi biologi. Definasikan dua sebutan ini.

(6 markah)

2. (a) Bezakan di antara kriteria kualiti air dan piawai kualiti air . Jelaskan kenapa selalunya kriteria kualiti air tidak sesuai diterima pakai secara terus dalam sesuatu program kawalan pencemaran.

(6 markah)

(b) Parameter kualiti air dibawah telah disukat untuk kepekatan nutrien dalam sebuah tasik.

Orthofosfat, PO_4^{3-}	10 $\mu g\ L^{-1}$
Fosforus Total (Terlarut)	15 $\mu g\ L^{-1}$
NO_3^- -N	15 $\mu g\ L^{-1}$
NH_4^+-N	10 $\mu g\ L^{-1}$

i) Apakah nutrien penghad untuk pertumbuhan alga dalam tasik ini berdasarkan nisbah dua nutrient tersebut?

ii) Bincangkan implikasi tasik yang mengalami peningkatan kandungan P total kepada nilai melebihi 0.5 mg L^{-1} akibat daripada pencemaran mengejut ke atas tasik tersebut.

(14 markah)

3. (a) Satu daripada impak agen pengkelat atau ligan dalam persekitaran akuatik ialah meningkatkan keterlarutan dan kegerakan logam berat. Contohnya kehadiran ligan NTA (asid nitrilotriasetik) meningkatkan keterlarutan $PbCO_3(s)$. Satu larutan yang mengandungi 25 mg L^{-1} Na_3NTA (BM = 257g mol^{-1}), pH 8.5 dan $[HCO_3^-]$ of 1.76 x 10^{-3} M telah diseimbangkan dengan $PbCO_3(s)$. Apakah nilai nisbah keseimbangan untuk $[Pb(NTA)]/[HNTA^{-2}]$? [rujuk lampiran untuk maklumat yang diperlukan]

(6 markah)

$PbCO_3\ (s) \rightleftharpoons Pb^{2+} + CO_3^{2-}$ $k_{sp} = 1.48 \times 10^{-13}$

$Pb^{2+} + NTA^{3-} \rightleftharpoons Pb\ (NTA^-)$ $k_f = 2.45 \times 10^{11}$

$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$ $ka_1 = 4.45 \times 10^{-7}$

$ka_2 = 4.69 \times 10^{-11}$

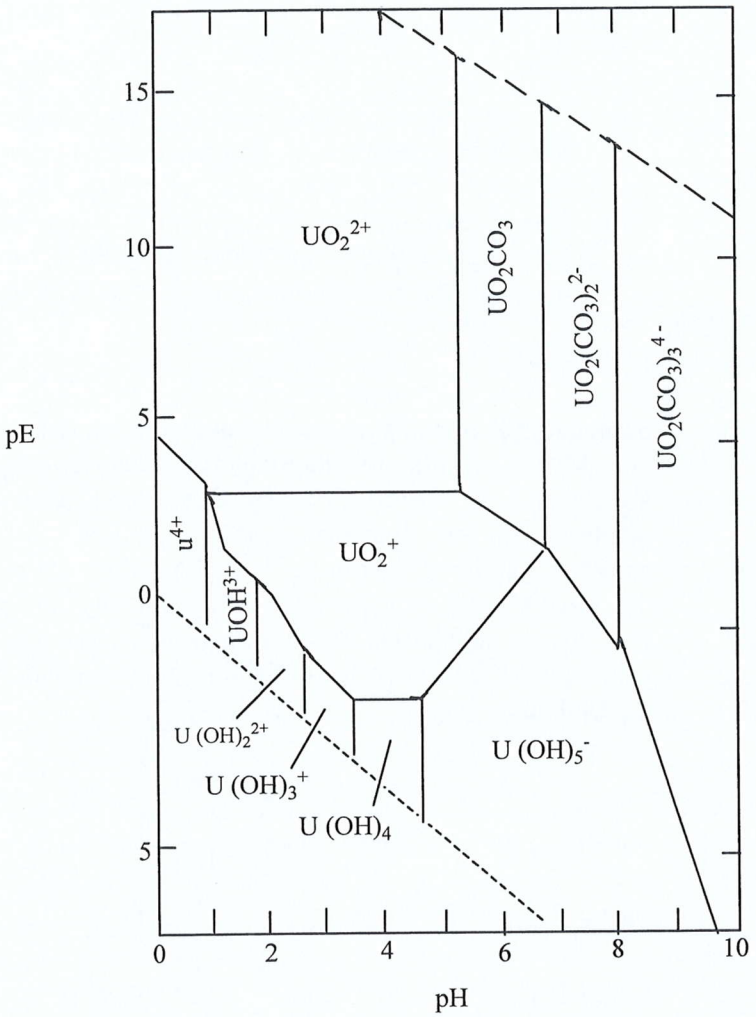
(b) Gunakan rajah pE-pH di bawah dan kefahaman anda tentang persekitaran metanogen (keadaan anaerobik) untuk menjawab soalan-soalan berikut:

(a) Apakah jenis uranium yang diramalkan dominan dalam persekitaran penghasilan metana pada pH 6.5.

(b) Apakah bentuk yang anda jangka sebagai dominan dalam air oksik pada pH 7.0 ?

(c) Kira nilai pE bagi kedua-dua persekitaran dalam (i) dan (ii) di atas .

(8 markah)



(c) Jelaskan bagaimana ion Hg^{2+} ditransformasikan kepada monometilmerkuri dan kenapa merkuri organik ini jauh lebih toksik dan boleh dikumpulkan secara biologi berbanding dengan ion Hg^{2+} asal.

(6 markah)

4 (a) Satu ujian BOD telah dilakukan ke atas 100 mL air buangan terolah yang dicampurkan dengan 200 mL air tulen .DO awal untuk campuran ini ialah 9.0 mg L^{-1}. Selepas 5 hari , DO ialah 4.0 mg L^{-1}. Selepas satu jangkamasa yang panjang , DO ialah 2.0 mg L^{-1}dan tidak lagi didapati menurun. Anggaplah nitrifikasi telah dibantutkan dan BOD yang disukat adalah daripada jenis berkarbon.

i) Apakah nilai BOD 5-hari untuk air buangan ini ?

ii) Anggarkan BOD ultimat (mg L^{-1}) berkarbon untuk air buangan ini

(5 markah)

(b) Sebuah bandar dengan penduduk seramai 200,000 orang mengeluarkan 1.048 m^3s^{-1} air kumbahan yang mempunyai nilai BOD_U sebanyak 28.0 mgL^{-1} dan kepekatan DO sebanyak 1.8 mgL^{-1} kedalam sebuah sungai yang mengalir pada kadar 7.079 m s^{-1} dan kelajuan 0.366 ms^{-1}. Pada hulu sungai yang tidak jauh daripada tempat discas , sungai ini mempunyai nilai BOD 3.6 mgL^{-1} dan DO 8.5 mg L^{-1}. Kadar pekali penyahoksigenan (k_1) ialah 0.60 $hari^{-1}$ dan pekali pengudaraan kembali (k_2) ialah 0.76 $hari^{-1}$. Tentukan kepekatan minimum oksigen terlarut dan jarak kawasan oksigen minimum tersebut daripada kawasan discas. Juga, lakarkan suatu keluk kepekatan oksigen terlarut melawan masa dan tentukan masa bagi mencapai nilai minimum DO dan tunjukkan masa ia kembali pulih kepada kepekatan asal DO iaitu 7.6 mg L^{-1}.

(15 markah)

Bahagian B

5 (a) Adalah dianggarkan terdapat 4800 mL darah di dalam badan sesorang Berdasarkan kepada kepekatan O_2 dalam udara yang kita hidu, terdapat 20 mL O_2 per 100 mL darah . Kita menyedut udara pada kadar 4.2 liter per minit dan kepekatan CO dalam atmosfera ialah 100 ppm.

i) Tukarkan kepekatan CO yang diberikan daripada ppm kepada $\mu g. m^{-3}$.

ii) Dapatkan masa (dalam minit) untuk darah menjadi 7% tepu dengan CO sekiranya darah tersebut pada peringkat awalnya adalah 0% tepu dengan CO.

(10 markah)

(b) Dalam atmosfera, NO bertindakbalas dengan O_3 untuk menghasilkan NO_2 dan O_2. Nitrik oksida juga bertindakbalas dengan radikal hidroperoksil (HO_2) untuk menghasilkan NO_2 dan radikal hidroksil (OH). Sebaliknya, NO_2 difotolisikan dengan pantas untuk menghasilkan NO dan atom oksigen . Oksigen atom bergabung segera dengan O_2 (dibantu oleh M) untuk menghasilkan O_3. Tuliskan persamaan kimia yang seimbang untuk mewakili keempat-empat tidak balas kimia tersebut.

(4 markah)

(c) Sekumpulan awan yang mengandungi NO_2 bergerak ke arah satu kawasan yang diketahui mengandungi kepekatan hidrokarbon yang tinggi yang berpunca daripada sumber industri. Sekiranya kawasan tersebut menerima sinaran terik matahari, apakah kesan pencemaran ke atas alam sekitar dikawasan tersebut ? Jelaskan jawapan anda.

(6 markah)

6. (a) Loji penjana kuasa elektrik yang menggunakan arang batu memancarkan gas SO_2 hasil daripada pengoksidaan S yang terdapat di dalam arang batu tersebut. Gas SO_2 ini telah dibuktikan menjadi punca kepada hujan asid. Penghasilan hujan asid ini dikatakan berlaku melalui pengoksidaan gas SO_2 kepada asid sulfurik dalam fasa gas dan fasa akueus. Berikan mekanisme proses pengoksidaan SO_2 di dalam kedua-dua fasa tersebut.

(8 markah)

(b) Bincangkan peranan awan stratosferik kutub dalam pembentukan lubang ozon di kutub selatan. Berikan persamaan-persamaan kimia yang penting untuk memperjelaskan hujah anda.

(12 markah)

7. (a) Dengan menggunakan gambarajah dan persamaan yang bersesuaian, berikan penjelasan bagi beberapa fenomena dalam meteorologi pencemaran udara

i) Kadar langkau superadiabatik secara normalnya dikaitkan dengan atmosfera amat yang tidak stabil .

ii) Sonsangan sinaran biasanya berlaku pada masa permulaan malam.

(10 markah)

LAMPIRAN

1. Jadual Pencairan Analisis BOD

Melalui Penyukatan Terus		Melalui Pencampuran [Isipadu Air Buangan] [Isipadu Total Campuran]	
Air Buangan (mL)	**Julat BOD (mg L^{-1})**	**Peratus Campuran**	**Julat BOD (mg L^{-1})**
0.20	3000 – 10,500	0.10	2000 – 7000
0.50	1200 – 4200	0.20	1000 – 3500
1.0	600 – 2100	0.50	400 – 1400
2.0	300 – 1050	1.0	200 – 700
5.0	120 – 420	2.0	100 – 350
10.0	6 – 210	5.0	40 – 140
20.0	30 – 105	10.0	20- 70
50.0	12 – 42	20.0	10 – 35
100	6 – 21	50.0	4 – 14

2. Jadual Nilai DO Tepu Bagi Air Pada Suhu Yang Berbeza.

Suhu (°C)	DO (mg L^{-1})
18	9.5
19	9.4
20	9.2
21	9.0
22	8.8
23	8.7
24	8.5
25	8.4
26	8.2
27	8.1
28	7.9
29	7.8
30	7.6

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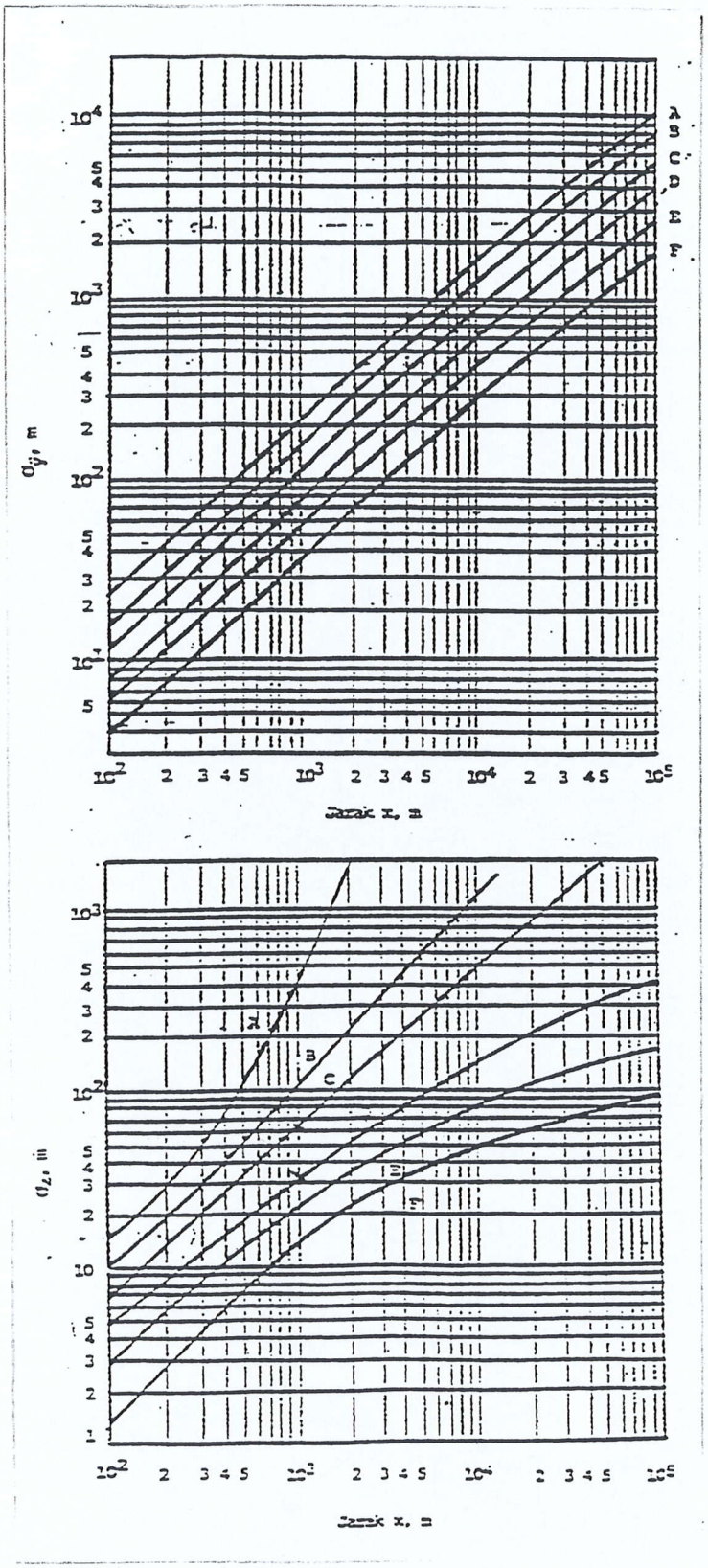

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Jadual pekali untuk nilai σ_Z

Kelas Kestabilan Atmosfera	Jarak Dihilir angin (meter) 100 < x ≤ 500		Jarak Dihilir angin (meter) 500 < x ≤ 5000		Jarak Dihilir angina (meter) 5000 < x	
	a	b	a	b	a	b
A = 1	.0383	.1281	.0002539	2.089	.0002539	2.089
B = 2	.1393	.9467	.04936	1.114	.04936	1.114
C = 3	.1120	.9100	.1014	.926	.1154	.9109
DD = 4	.0856	.8650	.2591	.6869	.7368	.5642
DN = 5	.0818	.8155	.2527	.6341	1.297	.4421
E = 6	.1094	.7657	.2452	.6358	.9204	.4805
F = 7	.05645	.8050	.1930	.6072	1.505	.3662

Jadual pekali untuk nilai σ_Y

Kelas Kestabilan Atmosfera	Jarak Dihilir angin (meter) x < 10,000		Jarak Dihilir angin (meter) x ≥ 10,000	
	a	b	c	d
A = 1	.495	.873	.606	.851
B = 2	.310	.897	.523	.840
C = 3	.197	.908	.285	.867
DD = 4	.122	.916	.193	.865
DN = 5	.122	.916	.193	.865
E = 6	.0934	.912	.141	.868
F = 7	.0625	.911	.0800	.884

Jisim Atom Relatif (JAR)

H = 1; C = 12; N = 14; O = 16; P = 31

S= 32 dan Fe = 55.8

-oooOooo-