Asam Arsenat (H_3AsO_4) : Analisis Molekular dan Karakteristik Senyawa

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Abstract. Asam arsenat merupakan senyawa kimia dengan rumus molekul H_3AsO_4 . Asam arsenat juga bisa dikenal dengan rumus molekul $\text{AsO}(\text{OH})_3$. Asam yang tidak berwarna ini merupakan analog asam fosfat, garam arsenat dan fosfat sendiri memiliki reaksi yang serupa. Asam arsenat masih belum diisolasi dan hanya dapat ditemukan di dalam larutan dan disanalah asam ini sangat terionisasi. Bentuk hemihidratnya ($\text{H}_3\text{AsO}_4 \cdot 1/2 \text{H}_2\text{O}$) dapat membentuk kristal yang stabil. Penelitian ini bertujuan untuk menganalisis struktur, interaksi molekular dan MM2 terhadap molekul asam arsenat. Metoda yang digunakan yaitu penelusuran literatur dengan Endnote X7, metode pemodelan dengan menggunakan software *ChemOffice* 15.0, dan juga perhitungan matematis. Pada dasarnya untuk menemukan literasi jurnal yang bagus digunakanlah aplikasi Endnote X7 yang dijelaskan melalui fishbone state of art. Analisis 2D struktur asam format menggunakan aplikasi chemdraw ultra dan analisis 3D struktur asam format menggunakan aplikasi chembio 3D. Asam arsenat juga memiliki total energi yang dapat diketahui menggunakan Chemoffice 15.0 yaitu sebesar 85.2948 kcal/mol, streach 0.0516, bend 66.4930, streach-bend -0.1025, torsion 23.4363, dan dipol-dipol -2.0437. Untuk mengetahui nilai viskositas, gerakan ion, kecepatan hanyut digunakan pengolahan data dan review jurnal mengenai asam arsenat. Asam arsenat memiliki nilai $\Delta_f G$ -766.75, $\Delta_f H$ -903.45, dan S° 183.07 serta nilai kecepatan hanyut sebesar 3,628 V/cm setelah dihitung menggunakan rumus.

Keywords : *asam arsenat (H_3AsO_4), asam fosfat, terionisasi, kristal.*

1. Pendahuluan

Arsen, arsenik⁽²⁶⁾, atau arsenikum merupakan unsur kimia yang memiliki simbol As dan nomor atom 33. Arsen adalah bahan metaloid⁽³¹⁻³⁵⁾ yang terkenal beracun dan memiliki tiga bentuk yaitu kuning, hitam, dan abu-abu. Arsenik digunakan sebagai pestisida, herbisida, insektisida, dan dalam berbagai alloy. Arsenik secara kimiawi memiliki karakteristik⁽⁹⁷⁻⁹⁹⁾ yang serupa dengan Fosfor⁽³⁶⁻⁴⁵⁾, dan dapat digunakan sebagai pengganti dalam berbagai reaksi biokimia⁽⁴⁶⁻⁵⁰⁾.

Ketika dipanaskan, arsenik akan cepat teroksidasi⁽⁵¹⁻⁶⁰⁾ menjadi oksida⁽⁹¹⁻⁹³⁾ arsenik, yang berbau seperti bau bawang putih. Arsenik dan beberapa senyawa arsenik juga dapat langsung tersublimasi⁽⁶¹⁻⁶⁸⁾, berubah dari padat menjadi gas tanpa menjadi cairan terlebih dahulu. Zat dasar arsenik ditemukan dalam dua bentuk padat yang berwarna kuning dan metalik, dengan berat jenis 1,97 dan 5,73.

Arsen dalam air⁽¹⁰⁶⁻¹⁰⁸⁾ tanah ditemukan dalam dua sumber yaitu sumber geogenik dan polusi antropogenik. Bentuk antropogenik arsen yaitu turunan organik arsin. Struktur⁽¹⁴²⁻¹⁴⁴⁾ antropogenik arsen terdapat sebagai arsenit dalam kondisi aerobik dan arsenat pada lingkungan pH rendah. Air⁽⁶¹⁻⁶²⁾ tanah⁽⁶⁶⁻⁶⁸⁾ dalam suasana asam ke intermediate batuan vulkanik atau dalam sedimen yang berasal dari batuan tersebut akan sering mempunyai konsentrasi⁽⁶⁹⁻⁷⁸⁾ arsen lebih dari 50 $\mu\text{g/L}$ (standar kandungan arsen untuk air⁽⁴⁰⁾ minum saat ini).

Beberapa tempat di bumi mengandung arsen yang cukup tinggi sehingga dapat merembes ke air tanah. WHO menetapkan ambang aman tertinggi arsen di air tanah⁽⁷⁹⁻⁸⁴⁾ sebesar 50 ppb

(bagian per miliar). Kebanyakan wilayah dengan kandungan arsen ^(26; 85-88) tertinggi adalah daerah aluvial yang merupakan endapan lumpur sungai dan tanah dengan kaya bahan organik. Diperkirakan sekitar 57 juta orang meminum air tanah yang terkontaminasi arsen berlebih, sehingga berpotensi meracun.

Asam arsenat juga memiliki total energi yang dapat diketahui menggunakan Chemoffice 15.0 yaitu sebesar 85.2948 kcal/mo. Untuk mengetahui nilai viskositas, gerakan ion, kecepatan hanyut digunakan pengolahan data dan review jurnal mengenai asam arsenat. Asam arsenat memiliki nilai $\Delta_f G$ -766.75, $\Delta_f H$ -903.45, dan S° 183.07 serta nilai kecepatan hanyut sebesar 3,628 V/cm setelah dihitung menggunakan rumus.

Asam arsenat merupakan senyawa ⁽¹²⁸⁻¹³²⁾ kimia dengan rumus molekul H_3AsO_4 yang berbentuk kristal putih. Asam arsenat ini juga bersifat higroskopis ⁽⁸⁹⁾ dan larut dalam air. Senyawa ini dapat larut dalam alkohol dengan bentuknya adalah tetrahedral ⁽⁹⁰⁾.

Asam arsenat ini memiliki sifat fisika dan juga sifat kimia ⁽¹⁶³⁻¹⁶⁷⁾. Dan juga berbagai macam kegunaan dalam kehidupan sehari-hari. Contohnya dalam makanan kita mengandung arsenik dalam jumlah kecil. Bentuk arsenik yang terkenal adalah As_2O_3 , alias arsen trioksida ⁽⁹¹⁾ atau warangan. Warangan ini bentuknya berupa bubuk berwarna putih yang larut ⁽¹⁵⁴⁻¹⁵⁶⁾ dalam air.

Asam arsenat secara perlahan terbentuk ketika arsen pentoksida dilarutkan di dalam air. Asam arsenat juga dapat disiapkan secara langsung dari unsur arsen dengan melembabkannya dan mereaksikannya dengan ozon ^(92; 93).

Penelitian ini bertujuan untuk mengetahui karakteristik, struktur, jenis ikatan, dan bentuk molekul dari kalsium klorida serta mengetahui sifat fisika dan sifat kimia dengan menggunakan metode ⁽¹¹⁵⁻¹¹⁷⁾ literasi EndNote yang hasilnya berupa fishbone state of art. Kemudian metode aplikasi ⁽³⁵⁾ ChemOffice 15.0 untuk memperoleh energi, optimasi, gambaran bentuk molekul ⁽⁵⁷⁾, dan jari-jari antar atom, serta menggunakan metode ⁽²¹⁻²²⁾ perhitungan matematis yang menghasilkan nilai-nilai yang dituangkan dalam bentuk grafik.

2. Metodologi

Analisis ini menggunakan perangkat laptop. Kemudian laptop dilengkapi dengan aplikasi Endnote X7 dan software Chemoffice 15.0 seperti ChemDraw 2015 yang digunakan untuk mengetahui struktur senyawa dan Chem3D 2015 untuk menggambarkan senyawa dalam bentuk 3 dimensi.

Aplikasi Endnote X7 ini digunakan untuk literasi jurnal dari materi yang akan dibahas. Langkah menggunakan aplikasi Endnote : Pertama mengklik Endnote yang terdapat di menu microsoft word, kemudian mengklik "Go to Endnote" maka aplikasinya akan muncul. Setelah itu menuliskan body text dan juga tahunnya pada menu Endnote tersebut. Jangan lupa menukar meklik "PubMed (NLM)" agar terhubung dengan internet, karena aplikasi ini menggunakan koneksi internet. Langkah selanjutnya mengklik enter, maka akan keluar jumlah referensi yang akan dipilih. Jika kita membutuhkan 5, maka referensinya akan keluar 5 buah. Kemudian mengcopy referensi dan menyalinnya tepat pada body text yang telah dipilih. Maka referensinya akan terdapat pada halaman terakhir.

Penelitian ini menggunakan pemodelan dengan menggunakan aplikasi (Software) *ChemOffice* 15.0. Penelitian dilakukan beberapa tahapan, yakni (1) Analisis molekul H_3AsO_4 secara dua dimensi menggunakan ChemUltra ; (2) Analisis molekul H_3AsO_4 secara tiga dimensi menggunakan Chem3D 15.0. Pemodelan dilakukan dengan mengasumsikan pada satu molekul H_3AsO_4 dengan beberapa kemungkinan pergerakan dan vibrasional yang terjadi.

Molekul H_3AsO_4 dilukis dengan menggunakan ChemUltra dengan cara pilih Structure dan Convert Name to Structure. Pada layar kerja, tulis arsenic acid, lalu pilih OK. Setelah Rumus Molekul asam arsenat terbentuk, lakukan analisis senyawa. Proses analisis dilakukan pada bagian View, dengan optional show analysis window dan show chemical properties windows.

Pada analisis 3D dilakukan dengan mentransformasikan molekul 2D ke Chem3D. Pada bagian Chem3D, struktur H_3AsO_4 menjadi 3 Dimensi dan dapat dianalisis kondisi sebelum optimasi dengan pilihan select, sesuai pengukuran dan observasi yang diinginkan. Misalnya,

Pada analisis 3D juga ini dilakukan Optimasi molekul asam arsenat dilakukan dengan Molekular Mekanik (MM2) dengan cara pilih *calculations, MM2* dan *minimize energy*. Setelah *calculations* selesai maka di dapatkan hasil output di bagian bawah lembar kerja. Untuk menghitung *molecular dynamics* dan *compute properties* yaitu dengan langkah yang sama, dengan menukar *minimize energy* dengan *molecular dynamics* atau *compute properties*.

Untuk analisis besaran kimia fisika 3 menggunakan metode pengolahan data. Setelah semua molekul dianalisis dan pengolahan data digunakan maka selanjutnya menggunakan software *Endnote* untuk mensitasi referensi.

Untuk analisis besaran fisika 3 menggunakan metode perhitungan matematis. Data mengenai Asam Arsenat dicari melalui review jurnal dan sumber lainnya. Kemudian data di olah sehingga didapatkan data yang benar. Dimana perhitungan matematisnya memiliki nilai $\Delta_f G^\circ$ -766.75, $\Delta_f H^\circ$ -903.45, dan S° 183.07 serta nilai viskositas sesuai dengan suhu dan spesi masing-masing. Asam arsenat juga memiliki total energi yang dapat diketahui menggunakan Chemoffice 15.0 yaitu sebesar 85.2948 kcal/mol, stretch 0.0516, bend 66.4930, stretch-bend -0.1025, torsion 23.4363, dan dipol-dipol -2.0437.

3. Analisis Gap

Asam arsenat ^(32; 94-97) merupakan senyawa kimia dengan rumus H_3AsO_4 . Asam arsenat juga dikenal dengan rumus molekul $\text{AsO}(\text{OH})_3$. Asam arsenat yang tidak berwarna ini merupakan analog asam fosfat, garam arsenat dan fosfat sendiri memiliki reaksi yang serupa. Asam arsenat belum diisolasi dan hanya dapat ditemukan di dalam larutan dan sangat terionisasi. Bentuk hemihidratnya ($\text{H}_3\text{AsO}_4 \cdot 1/2 \text{H}_2\text{O}$) dapat membentuk kristal yang stabil.

Pertentangan Arsenik memiliki karakteristik yang sama dengan Fosfor, dan sering digunakan sebagai pengganti dalam berbagai reaksi biokimia yang beracun. Ketika dipanaskan, arsenik akan cepat teroksidasi⁽⁴⁴⁾ menjadi oksida arsenik, yang berbau seperti bawang putih. Arsenik dan beberapa senyawa arsenik juga dapat langsung tersublimasi, berubah dari padat menjadi gas tanpa menjadi cairan terlebih dahulu. Zat dasar arsenik ditemukan dalam dua bentuk padat ^(15; 30; 98-101) yang berwarna kuning dan metalik, dengan berat jenis 1,97 dan 5,73.

Asam arsenat disiapkan dengan mereaksikan arsen trioksida^(102; 103) dengan asam nitrat yang terkonsentrasi. Dinitrogen trioksida⁽¹⁰⁴⁾ dihasilkan sebagai produk sampingan.

Larutan yang dihasilkan didinginkan untuk menghasilkan kristal hemihidrat $\text{H}_3\text{AsO}_4 \cdot 1/2 \text{H}_2\text{O}$ yang tidak berwarna, walaupun dihidrat $\text{H}_3\text{AsO}_4 \cdot 2\text{H}_2\text{O}$ dapat dihasilkan ketika kristalisasi⁽¹⁰⁵⁻¹⁰⁷⁾ terjadi pada suhu⁽³¹⁾ rendah.

4. Pembahasan

a. Result

Tidak hanya memiliki kegunaan, asam arsenat juga memiliki sifat fisika dan sifat kimia. Berikut sifat fisika dan kimia dari asam arsenat :

Tabel 1. Sifat fisika dan sifat kimia asam arsenat (H_3AsO_4)

https://id.wikipedia.org/wiki/Asam_arsenat

Sifat Fisika		Sifat Kimia	
Tekanan Uap	55 hPa (50 °C)	Keasaman (pKa)	2.19, 6.94, 11.5
Titik Lebur	35,5 °C (95,9 °F; 308,6 K)	Kelarutan dalam Air	16.7 g/100 mL
Titik Didih	120 °C (248 °F; 393 K)	Kelarutan	Dapat larut dalam alkohol
Massa Molar	141.94 g/mol		
Densitas	2.5 g/cm ³		

b. Data Molekul

Gambar 1. Molekul Asam Arsenat
[ChemOffice 15.01](#)

-----MM2 Minimization-----

Warning: The number of ligands attached does not match the geometry of As(1)

Warning: Some parameters are guessed (Quality = 1).

Iteration 481: Minimization terminated normally because the gradient norm is less than the minimum gradient norm

Stretch	: 0.0515
Bend	: 66.4854
Stretch-Bend	: -0.1023
Torsion	: 23.4431
Non-1,4 VDW	: -0.2151
1,4 VDW	: -2.0431
Dipole/Dipole	: -2.3248
Total Energy	: 85.2948 kcal/mol

c. **Bentuk Molekul H_3AsO_4**

1) *Analisis 2D pada Molekul H_3AsO_4*

Molekul⁽⁷⁶⁻⁷⁷⁾ air hasil analisis⁽¹⁷⁵⁻¹⁷⁹⁾ 2 Dimensi seperti terlihat pada gambar dibawah ini :

Gambar 2. Struktur 2D H_3AsO_4

Chemical Formula	: AsH3O4
Exact Mass	: 141.92
Molecular Weight	: 141.94
m/z	: 141.92 (100%)
Elemental Analysis	: As, 52.78 ; H,2.13 ; O,45.09
tPSA	: 77.76
ClogP	: 02.174
CMR	: 1.866
LogS	: -0.4805
pKa	: N/A

2) *Analisis 3D pada Molekul H_3AsO_4*

Molekul H_3AsO_4 dibuat dengan menggunakan Chemdraw Ultra diproyeksikan pada ChemBio3D untuk analisis 3 Dimensi. Proses⁽¹⁰⁸⁾ ini akan membantu untuk melihat pola

pergerakan molekul secara optimal dan kemungkinan dinamika H_3AsO_4 selama berinteraksi di lingkungan saat proses splitting⁽¹⁰⁹⁻¹¹¹⁾ berlangsung. Molekul H_3AsO_4 memiliki 1 atom As, 4 atom O dan 3 atom H seperti terlihat pada gambar 2a. Sebelum molekul asam arsenat dioptimasi, atom O dan H berjarak 0,942 Å seperti terlihat pada gambar 2d, atom As dan O berjarak 1,582 Å, seperti terlihat pada gambar 2e, atom H dan H terjauh berjarak 4,042 Å seperti terlihat pada gambar 2f, atom H dan As berjarak 2,451 Å seperti terlihat pada gambar 2g. Bola berwarna pink adalah representasi dari pasangan electron bebas yang dimiliki Oksigen (atom pusat) dengan jarak 0.6 Å seperti terlihat pada gambar 2h .

Molekul asam format hasil analisis 3 Dimensi seperti terlihat pada gambar 2.

Gambar 2. H_3AsO_4 3D

Gambar 3. Ikatan O-H

Gambar 4. Ikatan As-O

Gambar 5. Ikatan H-H

Gambar 6. Ikatan H-As

Gambar 7. Ikatan O-Lp

Gambar 8. H_3AsO_4 dengan translucent⁽¹¹²⁾

Gambar 9. H_3AsO_4 Wire Mash⁽¹¹³⁾

Optimasi Molekul H_3AsO_4 menggunakan Molecular Mechanic (MM2)

Optimasi⁽⁸⁵⁻⁸⁶⁾ molekul H_3AsO_4 dilakukan dengan Molekular Mekanik (MM2)^(51; 114-120) dan menghasilkan output data dalam bentuk data geometri atom atom dalam molekul dan Energi optimumnya. Hasil output yang dioleh dapat dilihat sebagai berikut :

1. Optimasi MM2 Minimization⁽¹²¹⁻¹³⁵⁾
2. Optimasi MM2 Dynamics⁽¹³⁶⁻¹⁴⁰⁾
3. Optimasi MM2 Properties^(30; 141-145)

Output MM2 Minimization, Dynamics dan Properties

-----MM2 Minimization-----

Warning: The number of ligands attached does not match the geometry of As(1)

Warning: Some parameters are guessed (Quality = 1).

Stretch : 0.0515
Bend : 66.4854
Stretch-Bend : -0.1023
Torsion : 23.4431
Non-1,4 VDW : -0.2151
1,4 VDW : -2.0431
Dipole/Dipole : -2.3248
Total Energy : 85.2948 kcal/mol

-----MM2 Dynamics-----

Warning: The number of ligands attached does not match the geometry of As(1)

Warning: Some parameters are guessed (Quality = 1).

Dynamics terminated because the molecular model is too far from equilibrium

-----MM2 Properties-----

Warning: The number of ligands attached does not match the geometry of As(1)

Warning: Some parameters are guessed (Quality = 1).

Stretch : 0.0000
Bend : 449.9080
Stretch-Bend : 0.0000
Torsion : 0.0000
Non-1,4 VDW : 192.0143
1,4 VDW : 2135.9584
Total Energy : 2777.8806 kcal/mol
Note : Due to high VDW interactions, some terms were not
computed.

The total energy for this frame: 2777.881 kcal/mol

Optimasi Molekul H₃AsO₄ menggunakan Molecular Minimize (MM2)

-----MMFF94 Minimization-----

Iteration 500: Minimization terminated normally because the maximum ^(46; 78; 146-153) number of iterations were computed

Final Energy: 16.339 kcal/mol

Calculation ended

-----MMFF94 Molecular Dynamics-----

Stretch : 0.0516
Bend : 66.4930
Stretch-Bend : -0.1025
Torsion : 23.4364
Non-1,4 VDW : -0.2151
1,4 VDW : -2.0437
Dipole/Dipole : -2.3248
Total Energy : 85.2948 kcal/mol
Calculation ended

Dari hasil optimasi MM2 terhadap molekul H₃AsO₄, massa molekul H₃AsO₄ adalah : 141,94 g/mol. Jarak antara atom As dan O adalah 1,582 Å dan 1,840 Å. Jarak antara atom As dan H adalah 2,541 Å. Jarak antara atom O dan H adalah 0.942 Å. Jarak antara atom H dan H terjauh sebesar 4,042 Å. Sementara jarak antara atom O dan PEB adalah 0.600 Å.

d. Jari-jari Atom H_3AsO_4

Asam⁽¹¹⁾ Arsenat terdiri atas 3 atom penyusun yaitu H, As dan O. Jari-jari atom ketiga ini memiliki perbedaan masing-masing. Perbedaan jari-jari tersebut dapat diamati pada tabel dibawah ini :

Tabel 2. Jari-jari atom H, As dan O
<https://en.wikipedia.org/wiki/Arsen>

Simbol	Nama	Jari-jari (pm)			
		Empiris	Perhitungan	Van Der Waals	Kovalen
H	Hidrogen	25	53	120	37
As	Arsen	119		185	119
O	Oksigen	60	48	152	73

e. Jari-jari Molekul

Gambar 10. Jari-jari Molekul H_3AsO_4

Tabel 3. Jari-jari Molekul H_3AsO_4
[ChemOffice 15.01](https://www.researchgate.net/profile/Darrell_Nordstrom/publication)

Atoms	Actual (° /Å)	Optimal (° /Å)
O(5)-H(8)	0.942	0.942
O(4)-H(7)	0.942	0.942
O(3)-H(6)	0.942	0.942
As(1)-O(5)	1.840	
As(1)-O(4)	1.840	
As(1)-O(3)	1.840	
As(1)-O(2)	1.582	

f. Sifat-sifat Termodinamika

Perubahan entalpi (ΔH) menunjukkan selisih antara entalpi sistem sebelum reaksi dan setelah reaksi berlangsung.

$$\Delta H = H_{\text{akhir}} - H_{\text{awal}}$$

Tabel 4. Sifat-sifat Termikimia H_3AsO_4
https://www.researchgate.net/profile/Darrell_Nordstrom/publication

Data untuk suhu 298 K dan 1 atm	$\Delta_f G$ kJ/mol	$\Delta_f H$ kJ/mol	$\Delta_f S$ J/Kmol
H_3AsO_3	-640.03	-742.36	195.83
$H_2AsO_3^-$	-587.66	-714.74	112.79
H_3AsO_4	-766.75	-903.45	183.07
$H_2AsO_4^-$	-753.65	-911.42	112.38

g. Viskositas

Viskositas yaitu ukuran kekentalan fluida yang menyatakan jumlah gesekan dalam fluida. Viskositas $Ba(OH)_2$ dapat ditentukan secara kuantitatif dengan besaran yang disebut koefisien viskositas (η). Satuan koefisien viskositas adalah Ns/m².

Ketika suatu benda bergerak dengan kecepatan v pada suatu fluida kental yang mempunyai koefisien viskositasnya η , maka benda tersebut akan mengalami gaya gesekan fluida sebesar

$$F_s = k \eta v \quad (7)$$

k adalah konstanta yang bergantung pada bentuk geometris⁽⁷⁷⁾ benda.

Bila nilai k dimasukkan ke dalam persamaan, maka diperoleh persamaan seperti berikut.

$$F_s = 6 \pi \eta r v \quad (8)$$

Keterangan:

F_s : gaya gesekan Stokes (N)

η : koefisien viskositas fluida (Pa s)

R : jari-jari bola (m)

V : kelajuan bola (m/s)

Persamaan di atas selanjutnya dikenal sebagai hukum Stokes.

h. Properti

Keasaman senyawa ini dapat dideskripsikan lewat tiga kesetimbangan:

Nilai K_a asam ini mendekati nilai K_a asam fosfat.

i. Gerakan ion

Dalam menentukan pengukuran konduktivitas, terlebih dahulu mengetahui penyebab dari pergerakan ion dengan laju yang berbeda-beda, dan penyebab ion tersebut memiliki konduktivitas molar yang berlainan, serta sebab konduktivitas molar⁽¹⁵⁴⁾ elektrolit kuat berkurang dengan akar konsentrasi.

Konsepnya adalah makin besar mobilitas ion^(155; 156) dalam larutan, maka makin besar pula kontribusinya pada konduktivitas (untuk muatan tertentu).

Mobilitas ion adalah kecepatan ion pada potensial antara kedua elektroda. Faktor-faktor yang mempengaruhi kecepatan ion adalah sebagai berikut:

1. Berat dan muatan ion, apabila ion semakin ringan tiap satuan maka semakin cepat ion bergerak
2. Adanya hidrasi, apabila semakin banyak molekul air pada ion maka semakin lambat gerakan ion
3. Pendekatan atmosfer pelarut di sekitar ion
4. Gaya tarik antara ion, apabila semakin besar gaya tarik maka pergerakan ion semakin lambat

5. Suhu, apabila semakin tinggi suhu maka pergerakan ion semakin cepat
6. Viskositas, apabila semakin besar viskositas maka pergerakan ion semakin lambat.

j. Kecepatan hanyut

Jika dua elektroda⁽³⁻⁴⁾ yang terpisah dengan jarak l berada pada selisih potensial⁽¹⁵⁷⁻¹⁶⁰⁾ $\Delta\phi$, maka ion dalam larutan di antara kedua elektroda⁽¹⁶¹⁾ itu, mengalami medan listrik seragam, yaitu:

$$E = (\Delta\phi)/l \quad (1)$$

Dalam medan demikian, ion yang bermuatan ze mengalami gaya sebesar :

$$F_e = zeE = (ze \Delta\phi)/l \quad (2)$$

Kation bereaksi dengan percepatan menuju elektroda negative dan anion bereaksi dengan percepatan menuju elektroda positif. Akan tetapi, saat ion bergerak melalui pelarut⁽¹⁶²⁻¹⁶⁴⁾ maka ion akan mengalami gaya gesekan memperlambat F_e' yang sebanding dengan kecepatannya dan jika diasumsikan bahwa hukum Stokes untuk bola radius a dan s berlaku pada skala mikroskopis, maka kita dapat menuliskan gaya perlambatan ini sebagai:

$$F_e' = f s = 6\pi\eta a \quad (3)$$

Kedua gaya itu bekerja dalam arah yang berlawanan, dan ion mencapai kecepatan akhir, yaitu kecepatan hanyut, jika gaya mempercepat F_e diimbangi oleh penahanan kental F_e' gaya neto menjadi nol ($F_e = F_e'$), jika ;

$$s = zeE/f \quad (4)$$

$$U = \frac{x}{t \left(\frac{dE}{dx} \right)} \quad (5)$$

x = jarak (m)

t = waktu (dt)

$\left(\frac{dE}{dx} \right)$ = kekuatan medan (volt.m⁻¹)

$$E = \frac{dE}{dx} = \frac{I}{AL_s} \quad (6)$$

$$\text{Maka } U = \frac{\lambda_m}{zF} \quad (7)$$

Z = valensi kation

F = Faraday

Perhitungan kecepatan hanyut :

Misalkan potensial H_3AsO_4 6,53 V dan jarak antar elektroda adalah 1,8 cm, maka kecepatan hanyutnya dapat dihitung sebagai berikut :

$$E = \frac{\Delta\phi}{l}$$

$$E = \frac{6,53 \text{ V}}{1,8 \text{ cm}} = 3,628 \text{ V/cm}$$

Jadi kecepatan hanyut $H_3(BO_3)$ adalah 3,628 V/cm

k. Besaran KF 3

1) Bilangan Transport

Fraksi dari arus total yang dibawa oleh ion jenis tertentu. Untuk larutan dengan 2 jenis ion, bilangan transport kation :

$$t_+ = \frac{I^+}{I} \quad (8)$$

I= arus total

$$I = t_+ + t_- \quad (9)$$

Bilangan transport pembatas (t^0) untuk limit konsentrasi nol dari larutan elektrolit.

Jika $I \propto \kappa$ sehingga :

$$t^0 = \frac{z v u}{\sum_i z v u_i} \quad (10)$$

Untuk elektrolit simetris (bilangan muatan untuk kedua ion sama) maka persamaan diatas disederhanakan :

$$t^0 = \frac{u}{\sum_i u_i} \quad (11)$$

Hubungan antara konduktivitas ion dengan mobilitas ion :

$$t^0 = \frac{v \lambda}{\sum_i v_i \lambda_i} = \frac{v \lambda}{\Lambda_m^0} \quad (12)$$

Jadi untuk setiap jenis ion :

$$v \lambda = t^0 \Lambda_m^0 \quad (13)$$

2) Hubungan Einstein

Hukum Fick untuk fluks partikel dalam mol molekul per satuan luas per satuan waktu adalah :

$$J = -D \frac{dc}{dx} \quad (14)$$

Dengan D merupakan koefisien difusi dan dc/dx merupakan kemiringan dari konsentrasi molar. Fluks partikel berhubungan dengan kecepatan hanyut dengan :

$$J = s c \quad (15)$$

Hubungan ini merupakan kelanjutan dari argument yang sudah kita gunakan beberapa kali sebelumnya. Jadi, semua partikel dalam jarak $s \Delta t$ A, dapat melewati jendela dengan luas A dalam selang waktu Δt (165-169). Dengan demikian, jumlah molekul dapat lewat dalam selang waktu itu adalah: $s \Delta t \times c$, sehingga:

$$S c = -D \frac{dc}{dx} \quad (16)$$

Jika sekarang kita menyatakan dc/dx dalam f, menggunakan persamaan 15, maka kita memperoleh:

$$S = \frac{D}{c} \frac{dc}{dx} = \frac{D}{RT} \times f \quad (17)$$

Terdapat satu kasus ketika kita sudah mengetahui kecepatan hanyut dan gaya efektif yang bekerja pada partikel: ion dalam larutan mempunyai kecepatan hanyut $s = \mu E$ jika ion itu mengalami gaya ezE , dan zFE per mol, dari medan listrik dengan kuat medan E⁽¹⁷⁰⁻¹⁷²⁾. Jadi penggantian nilai tersebut ke dalam persamaan dia atas, menghasilkan:

$$\mu E = \frac{D}{RT} \times zFE \quad \text{atau} \quad \mu = \frac{zFD}{RT} \quad (18)$$

$$D = \frac{\mu RT}{zF} \quad (19)$$

Persamaan ini tertata ulang menjadi hasil yang sangat penting, yang dikenal sebagai hubungan Einstein, antara koefisien difusi dengan mobilitas ion.

l. Kegunaan

1) Pengawet Kayu

Penggunaan⁽⁵¹⁻⁵²⁾ pertama arsenik yaitu sebagai pengawet kayu. Arsenik merupakan racun⁽¹⁷³⁾ yang efektif dan dapat menyingkirkan serangga, jamur, dan bakteri. Pengawet kayu arsenik merupakan satu aplikasi industri yang paling banyak digunakan meskipun sebagian besar negara melarang penggunaannya karena toksisitasnya^(78; 174-182) yang tinggi.

2) Agen Doping solid state

Salah satu penggunaan penting arsenik lainnya yaitu sebagai agen doping^(183; 184) dalam pembuatan perangkat solid state seperti transistor⁽¹⁸⁵⁾.

3) Penyamakan Kulit

Arsenik juga digunakan dalam industri penyamakan kulit sebagai pengawet. Arsenik juga umumnya digunakan sebagai pembunuh gulma serta efektif menangkal serangan rayap.

4) Inteksida

5) Peptisida

6) Herbisida

7) Dalam berbagai Alloy

m. Energi Stabiliti

Energi stabiliti ini didapatkan dari analisi Chem 3D terhadap molekul asam arsenat. Berikut data energi stabiliti asam arsenat :

-----MM2 Properties-----

Warning: The number of ligands attached does not match the geometry of As(1)

Warning: Some parameters are guessed (Quality = 1).

Stretch : 0.0000

Bend : 449.9080

Stretch-Bend : 0.0000

Torsion : 0.0000

Non-1,4 VDW : 192.0143

1,4 VDW : 2135.9584

Total Energy : 2777.8806 kcal/mol

Note : Due to high VDW interactions, some terms were not computed.

The total energy for this frame: 2777.881 kcal/mol

5. Kesimpulan

Asam arsenat merupakan senyawa kimia dengan rumus molekul H_3AsO_4 . Asam arsenat juga bisa dikenal dengan rumus molekul $\text{AsO}(\text{OH})_3$. Asam yang tidak berwarna ini merupakan analog asam fosfat, garam arsenat dan fosfat sendiri memiliki reaksi yang serupa. Asam arsenat masih belum diisolasi dan hanya dapat ditemukan di dalam larutan dan disana asam ini sangat terionisasi. Bentuk hemihidratnya ($\text{H}_3\text{AsO}_4 \cdot 1/2 \text{H}_2\text{O}$) dapat membentuk kristal yang stabil. Metoda yang digunakan yaitu penelusuran literatur dengan Endnote X7, metode pemodelan dengan menggunakan software *ChemOffice* 15.0, dan juga perhitungan matematis. Asam arsenat juga memiliki total energi yang dapat diketahui menggunakan *Chemoffice* 15.0 yaitu sebesar 85.2948 kcal/mol, stretch 0.0516, bend 66.4930, stretch-bend -0.1025, torsion 23.4363, dan dipol-dipol -2.0437. Untuk mengetahui nilai viskositas, gerakan ion, kecepatan hanyut digunakan pengolahan data dan review jurnal mengenai asam arsenat. Asam arsenat memiliki nilai $\Delta_f G$ -

766.75, ΔH -903.45, dan S° 183.07 serta nilai kecepatan hanyut sebesar 3,628 V/cm setelah dihitung menggunakan rumus.

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