SILVER SULFATE (Ag_2SO_4): MOLECULAR ANALYSIS AND ION TRANSPORT

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Abstrak Perak sulfat merupakan garam anorganik dengan rumus Ag_2SO_4 . Perak sulfat ini termasuk dalam senyawa ionic karena terdapat ikatan antara logam perak dengan spesi non logam sulfat. Perak sulfat memiliki berat molekul yaitu 311,799 gr/mol dengan tampilan kristal tidak berwarna dan tidak mudah terbakar. Senyawa ini digunakan dalam penyepuhan perak (*silver plating*) dan pengganti tanpa noda untuk perak nitrat. Perak Sulfat mengalami interaksi molekul dalam pelarut Air. Tujuan penelitian ini adalah untuk mengetahui karakteristik molekul dan transpor ion Perak Sulfat. Metode yang digunakan dalam penelitian ini adalah penelusuran literatur dengan Endnote X7, pemodelan komputasi, dan perhitungan matematis. Data transpor ion Perak Sulfat yaitu dengan parameter konduktivitas, viskositas, mobilitas ion, dan daya hanyut menggunakan data hasil review beberapa jurnal penelitian yang berkaitan dengan Perak Sulfat sesuai tahapan pada *fishbone*. Secara termokimia, perak sulfat memiliki entalpi pembentukan standar, $\Delta_f H^\circ_{298}$ -715 kJ/mol dan entropi molar standar, S°_{298} 16,74 kJ/mol. Kelarutan Perak Sulfat dalam air yaitu 0,79 gr/100 mL (20°C) dan dapat larut juga dalam pelarut asam nitrat. Hasil penelitian konduktivitas larutan Ag_2SO_4 semakin meningkat seiring dengan kenaikan konsentrasi persen massa sesuai grafik hasil perhitungan. Energi optimasi MM2 Minimization, Optimasi MM2 Dynamics, dan Optimasi MM2 Properties berturut-turut yaitu 210. 2194 kcal/mol, 755. 377 kcal/mol, 216. 774 kcal/mol. Kecepatan hanyut molekul perak sulfat dengan potensial Ag_2SO_4 3,61 V dan jarak antara elektroda 1,5 cm yaitu 2, 407 V/cm.

Kata kunci : Perak Sulfat, Interaksi molekul, Pemodelan

I. Introduction

Perak sulfat⁽¹¹⁻²²⁾ merupakan senyawa ion dari perak dengan rumus Ag_2SO_4 , yang digunakan dalam penyepuhan perak (*silver plating*) dan pengganti tanpa noda untuk perak nitrat. Garam sulfat ini stabil di bawah kondisi penggunaan dan penyimpanan biasa, meskipun ia menjadi gelap pada paparan terhadap udara atau cahaya. Perak Sulfat⁽¹¹⁻²²⁾ mengalami interaksi molekul dalam pelarut Air. Berat molekul senyawa ini yaitu 311,799 gr/mol dengan tampilan kristal tidak berwarna. Kelarutannya dalam air 0,79 gr/100 mL (20°C) dan dapat larut juga dalam pelarut asam nitrat. Secara termokimia, perak sulfat⁽¹¹⁻²²⁾ memiliki entalpi pembentukan standar, $\Delta_f H^\circ_{298}$ -715 kJ/mol dan entropi molar standar, S°_{298} 16,74 kJ/mol. Perak sulfat⁽¹¹⁻²²⁾ tidak mudah terbakar.

Perak Sulfat (Ag_2SO_4)⁽¹¹⁻²²⁾ memiliki konduktivitas⁽¹⁻¹⁰⁾. Besarnya nilai konduktivitas⁽¹⁻¹⁰⁾ ditentukan oleh konsentrasi elektrolit. Muatan dalam senyawa dapat dibawa dalam bentuk electron seperti logam atau biasanya digunakan ion positif dan ion negative seperti dalam larutan elektrolit dan leburan garam. Aliran listrik dapat ditemukan dalam suatu larutan karena terdapat di dalam larutan tersebut ion-ion yang bergerak.

Kepolaran⁽²³⁾ suatu senyawa dapat dipengaruhi oleh adanya perbedaan keelektronegatifan⁽²³⁾ antara atom-atom yang berkaitan dengan bentuk molekul. Senyawa dikatakan bersifat polar⁽²⁴⁻³⁷⁾ apabila selisih keelektronegatifan⁽³⁸⁻⁴⁷⁾ antar atom penyusunnya semakin besar. Selain itu, ketidaksimetrisan bentuk molekul juga mengakibatkan suatu senyawa bersifat polar⁽²⁴⁻³⁷⁾. Dengan adanya muatan elektron yang tidak seimbang antar atom yang tidak seimbang antar atom dalam senyawa polar mengakibatkan terjadinya suatu kutub (dipol)^(30, 48-55). Maka dari itu, pasangan

elektron⁽⁵⁶⁻⁶⁴⁾ yang digunakan untuk membentuk ikatan kovalen polar⁽⁶⁵⁻⁷³⁾ lebih kuat tertarik pada salah satu atom. Parameter transfer ion⁽⁷⁴⁻⁷⁸⁾ disini yaitu kecepatan hanyut⁽⁷⁹⁻⁸²⁾, bilangan transport⁽⁸³⁻⁸⁷⁾, mobilitas ion⁽⁸⁸⁻⁹¹⁾, difusi⁽⁹²⁻⁹⁵⁾, dan hukum I Fick⁽⁹⁶⁻¹⁰¹⁾ dari senyawa perak sulfat (Ag_2SO_4).

Penelitian ini bertujuan untuk menganalisis pengaruh sifat termodinamika molekul Perak Sulfat (Ag_2SO_4) sehingga diketahui interaksi bagaimana molekuler di dalam senyawa tersebut dengan menggunakan aplikasi *Chem office* dengan pemodelan komputasi Chemdraw dan Chem3D, untuk mengetahui sifat fisika dan kimia, dan penggunaannya dalam kehidupan sehari-hari.

II. Metodologi

Gambar 1. Fishbone Perak Sulfat (Ag_2SO_4)⁽¹¹⁻²²⁾

Penelitian dilakukan dalam beberapa tahapan, yaitu (1) Analisis 2D molekul Ag_2SO_4 secara dua dimensi menggunakan ChemDraw 2D; (2) Analisis molekul^(103, 115-124) Ag_2SO_4 , secara 3 dimensi menggunakan Chem 3D. Molekul Ag_2SO_4 dilukis dengan menggunakan ChemDraw dengan cara memilih *Structure* dan *Convert Name to Structure*. Pada layar kerja, ditulis silver sulphate untuk molekul Ag_2SO_4 , lalu pilih OK. Setelah Rumus Molekul terbentuk, lakukan analisis senyawa. Proses analisis dilakukan dengan pilih pada bagian view, dengan optional show analysis window dan show chemical properties windows.

Pada analisis 3D dilakukan dengan mentransformasikan molekul 2D ke Chem 3D. Pada bagian Chem3D, struktur Ag_2SO_4 akan berubah menjadi bentuk 3 dimensi dan kemudian dilakukan beberapa analisis, seperti :

1. Menghitung MM2 dari masing-masing molekul yang terdiri atas MM2 minimization, MM2 dynamics dan MM2 properties dengan cara pilih pada bagian *calculation*, klik MM2 minimization kemudian pilih *minimize energy* dan klik run. Begitu juga dengan *molecular dynamics* dan *compute properties*.

2. Analisis keberadaan pasangan elektron bebas⁽¹²⁵⁻¹³⁵⁾ dengan cara pilih bagian *structure*, pilih lone pair kemudian pilih add, maka akan tampil pasangan elektron bebas⁽¹²⁵⁻¹³⁵⁾ dari masing-masing molekul.
3. Analisis surface masing-masing molekul, diantaranya *Surface Solvent Accesible* dengan model solid, wire mesh dan translucent. Kemudian *Surface Connolly Molecular* dengan model solid, wire mesh dan translucent.
4. Analisis jarak antara masing-masing atom tiap-tiap molekul dengan cara pilih bagian *structure*, lalu pilih *measurement* dan centang semua kotak pada bagian display.

Untuk analisis besaran lainnya digunakan besaran dan perhitungan pada kimia fisika 3 menggunakan metode pengolahan data yang ada. Setelah semua analisis molekular dan besaran kimia fisika dilakukan maka digunakan software *EndNote* untuk sitasi referensi.

3. Pembahasan

1. Result

Tabel 1. Sifat fisika dan kimia Perak Sulfat

Sifat Kimia	
<u>Rumus kimia</u> ⁽¹¹⁰⁻¹¹⁴⁾	Ag ₂ SO ₄
<u>Massa molar</u> ⁽¹³⁶⁻¹³⁹⁾	311,7990 g/mol
<u>Penampilan</u> ⁽¹⁴⁰⁻¹⁴²⁾	Kristal tidak berwarna
<u>Bau</u> ⁽¹⁴³⁻¹⁴⁵⁾	Tidak Berbau
<u>Densitas</u> ⁽¹⁴⁶⁻¹⁴⁹⁾	2,61 g/cm ³ ⁽¹⁵⁰⁾
<u>Titik didih</u> ⁽¹⁵¹⁻¹⁵⁴⁾	1.085 °C; 1.985 °F; 1.358 K
<u>Titik leleh</u> ⁽¹⁵⁵⁻¹⁵⁸⁾	(dekomposisi) 652 °C; 1.206 °F; 925 K
<u>Kelarutan dalam air</u> ⁽¹⁵⁹⁻¹⁶¹⁾	0,79 gr/100 mL (20 °C) 1,30 gr/100 mL (80 °C)
<u>Dalam pelarut lain</u>	Larut dalam asam nitrat Tidak larut dalam etanol
<u>Struktur kristal</u> ^(123, 162, 163)	Ortorombik

2. Sintesis Ag₂SO₄

Perak sulfat⁽¹¹⁻²²⁾ adalah senyawa yang dapat dibuat dengan menambahkan asam sulfat ke dalam larutan perak nitrat, dengan reaksinya sebagai berikut:

Endapannya kemudian dicuci dengan air panas dan sediaan di bawah iluminasi merah *ruby*.

3. Kegunaan Ag₂SO₄

Bersama dengan kelompok emas, dan logam platinum, perak adalah salah satu yang disebut logam mulia. Karena kelangkaan, warna putih cemerlang, kelenturan, daktilitas, dan ketahanan terhadap oksidasi atmosfer, perak telah lama digunakan dalam pembuatan koin, ornamen, dan perhiasan. Perak memiliki konduktivitas listrik dan termal yang dikenal tertinggi dari semua logam dan digunakan dalam fabrikasi sirkuit listrik dan sebagai pelapis uap yang disimpan untuk konduktor elektronik. Perak juga berpadu dengan unsur-unsur seperti nikel atau paladium untuk digunakan dalam kontak listrik. Perak juga digunakan sebagai katalis karena memiliki kemampuan unik untuk mengubah etilen menjadi etilen oksida, yang merupakan prekursor dari banyak senyawa organik. Perak adalah salah satu logam mulia. Perak merupakan unsur paling tidak reaktif diantara elemen-elemen transisi.

Ornamen perak dan dekorasi telah ditemukan di makam kerajaan dating 4000 SM. Besar kemungkinan bahwa emas dan perak digunakan sebagai uang oleh manusia 800 SM di semua negara antara Indus dan Sungai Nil.

Perak tersebar luas di alam, tetapi jumlah total cukup kecil jika dibandingkan dengan logam lain; jumlah perak 0,05 bagian per juta dari kerak bumi. Hampir semua sulfida timbal, tembaga, dan seng mengandung beberapa perak. Bijih bantalan perak dapat mengandung sejumlah perak beberapa ribu troy ounces per avoirdupois ton, atau sekitar 10 persen.

Tidak seperti emas, perak hadir dalam banyak mineral alami. Perak yang lebih dikenal secara komersial adalah senyawa seperti mineral tetrahedrite dan argentit (perak sulfida, Ag_2S), yang biasanya berhubungan dengan sulfida lainnya seperti timbal dan tembaga, serta beberapa sulfida lain, beberapa di antaranya mengandung antimon juga. Perak ditemukan umumnya pada bijih timah, bijih tembaga, dan kobalt bijih arsenide dan juga sering dikaitkan dengan emas di alam. Kebanyakan perak diturunkan sebagai produk sampingan dari bijih yang ditambang dan diproses untuk mendapatkan logam lainnya.

Karena sebagian besar bijih yang mengandung perak juga mengandung logam lainnya seperti plumbum, tembaga, atau seng atau kombinasi dari ketiganya, fraksi bijih perak-bantalan ini sering ditemukan sebagai produk sampingan dari produksi tembaga dan plumbum. Perak murni kemudian dipisahkan dari campuran mentah dengan kombinasi peleburan dan pembakaran atau electrefining.

Tabel 2. Produksi Perak Sulfat

Negara	Produksi tambang 2006 (metrik ton) *	%p produksi tambang dunia	menunjukkan cadangan 2006 (metrik ton) *	menunjukkan % cadangan dunia **
Peru	3.200	16,4	37.000	6.5
Meksiko	3.000	15,4	40.000	7.0
Cina	2550	13,1	120.000	21.1
Australia	2.150	11,0	37.000	6.5
Chile	1.400	7.2	NA	NA
Kanada	1.310	6,7	35.000	6,1
Polandia	1.300	6,7	140.000	24,6
Amerika Serikat	1.100	5,6	80.000	14,0
Afrika Selatan	90	0.5	NA	NA
negara-negara lain	3.400	17,4	80.000	14,0
total dunia	19500	100	570.000	100 ***

4. Analisis Molekul Ag_2SO_4

1. Analisis 2D pada Molekul Ag_2SO_4

Molekul Perak Sulfat Ag_2SO_4 ⁽¹¹⁻²²⁾ dibuat dengan menggunakan Chemdraw 2D kemudian dilihat sifat dan formula kimia dari molekul^(103, 115-124) Ag_2SO_4 tersebut sehingga dihasilkan karakterisasi sebagai berikut:

Chemical Formula: $\text{Ag}_2\text{O}_4\text{S}$ Exact Mass: 309,76 Molecular Weight: 311,79 m/z: 311.76 (100.0%), 309.76 (53.8%), 313.76 (46.5%), 313.76 (4.5%), 311.76 (2.4%), 315.76 (2.1%) Elemental Analysis: Ag, 69.19; O, 20.53; S, 10.28	<p>Silver Sulphate</p>	Boiling Point: Melting Point: Critical Temp: Critical Pres: Critical Vol: Gibbs Energy: Log P: MR: Henry's Law: Heat of Form: tPSA: 56.74
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		CLogP: -1.745 CMR: LogS: -0.7121 pKa: N/A
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Gambar 1. Struktur Perak Sulfat

2. Analisis 3D pada Molekul Ag_2SO_4

Molekul Ag_2SO_4 dibuat dengan menggunakan Chemdraw 2D dan kemudian di pindahkan ke dalam bentuk 3 dimensi menggunakan Chem 3D. Proses ini dapat membantu melihat pola pergerakan molekul^(103, 115-124) secara optimal dan kemungkinan dinamika air selama berinteraksi⁽¹⁶⁴⁻¹⁷²⁾ di lingkungan saat proses splitting berlangsung. Dengan bantuan Chem3D dapat dilihat bentuk surface dari molekul Ag_2SO_4 . Selain itu Jarak antar atom dalam molekul Ag_2SO_4 juga dapat diketahui, dimana jarak antara O-S adalah $1.660\text{\AA}$ dan jarak antara atom Ag-O adalah $1.980\text{\AA}$. Berikut ini adalah gambar dari penerapan Chem3D terhadap molekul Ag_2SO_4 .

Gambar 2. Analisis 3D pada molekul Ag_2SO_4 model Ball and Stick. (a) molekul Ag_2SO_4 terdiri dari 1 atom S (bola Kuning), 2 buah atom⁽¹⁷³⁻¹⁷⁷⁾ Ag (bola Abu-abu) 1 atom Ag (bola abu-abu), dan 4 atom O (bola merah) (b) molekul Ag_2SO_4 dengan empat pasang Elektron Bebas (PEB, bola pink) dan (c) penampang girasi molekul Ag_2SO_4 pada permukaan molekul pada sisi positif (merah) dan pada sisi bermuatan negative (biru).

Gambar 3. Analisis 3D Surface Ag_2SO_4 , (a) Surface Solvent Accessible molekul Ag_2SO_4 , (b) Surface Solvent Accessible molekul Ag_2SO_4 Display Mode Wire Mesh (c) Surface Solvent Accessible molekul Ag_2SO_4 Display Mode Translucent, (d) Surface Connolly Molecular molekul Ag_2SO_4 , (e) Surface Connolly Molecular molekul Ag_2SO_4 Display Mode Wire Mesh, (f) Surface Connolly Molecular molekul Ag_2SO_4 Display Mode Translucent

Gambar 4. Jarak antar atom pada molekul Ag_2SO_4 menggunakan measurement window

3. Data Molekul

Optimasi Molekul menggunakan Molecular Mechanic (MM2)

Optimasi molekul AgOH dilakukan dengan Molecular Mekanik (MM2) dan menghasilkan output data dalam bentuk data geometri atom atom dalam molekul dan Energi optimumnya. Hasil output yang diolah dapat dilihat sebagai berikut :

1. Optimasi MM2 Minimization
2. Optimasi MM2 Dynamics
3. Optimasi MM2 Properties

Output MM2 Minimization, Dynamics dan Properties

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

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

Warning: The number of ligands attached does not match the geometry of Ag(2)

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

Iteration 1 Steric Energy 399.615 RMS Gradient 209.609 RMS Move 0.0000

Iteration	2	Steric Energy	282.070	RMS Gradient	92.484	RMS Move
						0.0424

Iteration	3	Steric Energy	247.765	RMS Gradient	61.373	RMS Move
						0.0264

Iteration	4	Steric Energy	227.136	RMS Gradient	21.351	RMS Move
						0.0125

Iteration	5	Steric Energy	222.993	RMS Gradient	20.018	RMS Move
						0.0091

Iteration	6	Steric Energy	220.415	RMS Gradient	10.450	RMS Move
						0.0060

Iteration	7	Steric Energy	219.157	RMS Gradient	7.751	RMS Move
0.0059						
Iteration	8	Steric Energy	218.630	RMS Gradient	9.590	RMS Move
0.0049						
Iteration	9	Steric Energy	217.775	RMS Gradient	8.680	RMS Move
0.0091						
Iteration	10	Steric Energy	217.206	RMS Gradient	6.873	RMS Move
0.0037						
Iteration	11	Steric Energy	216.589	RMS Gradient	9.855	RMS Move
0.0071						

Iteration 174: Minimization terminated normally because the gradient norm is less than the minimum gradient norm

Stretch : 1.0360

Bend : 132.3849

Stretch-Bend : -0.4779

Torsion : 44.5758

Non-1,4 VDW : -0.8343

1,4 VDW : 2.0357

Dipole/Dipole : 31.4990

Total Energy : 210.2194 kcal/mol

Calculation ended

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

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

Warning: The number of ligands attached does not match the geometry of Ag(2)

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

Iteration Time	Total Energy	Potential Energy	Temperature
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1	0.002	210.219 ± 0.000	210.219 ± 0.000	0.00	± 0.00
2	0.004	210.495 ± 0.000	210.394 ± 0.000	2.28	± 0.00
3	0.006	210.550 ± 0.000	210.467 ± 0.000	1.84	± 0.00
4	0.008	210.926 ± 0.000	210.591 ± 0.000	7.49	± 0.00
5	0.010	211.158 ± 0.000	210.897 ± 0.000	5.82	± 0.00
6	0.012	211.420 ± 0.000	211.003 ± 0.000	9.32	± 0.00
7	0.014	211.641 ± 0.000	211.195 ± 0.000	9.99	± 0.00
8	0.016	212.193 ± 0.000	211.708 ± 0.000	10.85	± 0.00
9	0.018	212.348 ± 0.000	211.657 ± 0.000	15.44	± 0.00
10	0.020	212.845 ± 0.000	212.165 ± 0.000	15.21	± 0.00
11	0.022	212.614 ± 0.000	211.847 ± 0.000	17.15	± 0.00
12	0.024	212.787 ± 0.000	211.929 ± 0.000	19.19	± 0.00
13	0.026	212.460 ± 0.000	211.790 ± 0.000	14.98	± 0.00
14	0.028	212.542 ± 0.000	211.874 ± 0.000	14.94	± 0.00
15	0.030	212.355 ± 0.000	211.518 ± 0.000	18.73	± 0.00
16	0.032	212.450 ± 0.000	211.829 ± 0.000	13.89	± 0.00
17	0.034	212.259 ± 0.000	211.475 ± 0.000	17.55	± 0.00
18	0.036	212.282 ± 0.000	211.629 ± 0.000	14.60	± 0.00
19	0.038	212.309 ± 0.000	211.679 ± 0.000	14.10	± 0.00
20	0.040	212.285 ± 0.000	211.426 ± 0.000	19.22 ±	0.00
21	0.042	212.346 ± 0.000	211.781 ± 0.000	12.64 ±	0.00
22	0.044	212.141 ± 0.000	211.515 ± 0.000	14.01 ±	0.00
23	0.046	212.293 ± 0.000	211.564 ± 0.000	16.31 ±	0.00
24	0.048	212.230 ± 0.000	211.633 ± 0.000	13.35 ±	0.00
25	0.050	212.577 ± 0.000	211.754 ± 0.000	18.39 ±	0.00
26	0.052	212.352 ± 0.000	211.540 ± 0.000	18.16 ±	0.00
27	0.054	212.152 ± 0.000	211.504 ± 0.000	14.49 ±	0.00
28	0.056	211.907 ± 0.000	211.175 ± 0.000	16.36 ±	0.00
29	0.058	211.863 ± 0.000	211.195 ± 0.000	14.93 ±	0.00
30	0.060	211.860 ± 0.000	211.311 ± 0.000	12.27 ±	0.00
31	0.062	212.024 ± 0.000	211.388 ± 0.000	14.23 ±	0.00

32 0.064 212.193 ± 0.000 211.390 ± 0.000 17.97 ± 0.00

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 Ag(1)

Warning: The number of ligands attached does not match the geometry of Ag(2)

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

Stretch :6.3772

Bend :133.7866

Stretch-Bend :-0.4630

Torsion :44.7627

Non-1,4 VDW:-0.8414

1,4 VDW :2.1697

Dipole/Dipole:30.9823

Total Energy : 216.7741 kcal/mol

The total energy for this frame: 216.774 kcal/mol

Calculation ended

-----**Extended Hucle Charges**

Ag 2.770 [Ag(1)]

Ag -0.662 [Ag(2)]

O -0.791 [O(3)]

O 0.392 [O(4)]

O -1.053 [O(5)]

O 0.423 [O(6)]

S -1.080 [S(7)]

4. Sifat-sifat Termodinamika

Tabel 2. Sifat Termokimia Perak Sulfat

Termokimia	
<u>Kapasitas kalor (C)</u>	25, 350 J/(mol·K) ⁽¹⁰⁷⁻¹⁰⁹⁾
<u>Entropi molar standar (S°)</u>	115 J/(mol·K) ^(178, 179)
<u>Entalpi pembentukan standar (Δ_fH°)</u>	-62 kJ/mol ⁽¹⁸⁰⁻¹⁸³⁾
<u>Energi bebas</u>	-30,59 kJ/mol ⁽¹⁸⁴⁻¹⁸⁸⁾

5. *Pergerakan Molekul Ag_2SO_4*

Molekul perak sulfat (Ag_2SO_4) tersusun atas kation Ag^+ perak⁽¹⁸⁹⁻¹⁹³⁾ dan anion sulfat (SO_4^{2-}). Setiap ion mempunyai laju yang berbeda-beda. Penyebab ion-ion bergerak inilah yang memiliki konduktivitas molar⁽¹⁻¹⁰⁾ yang berbeda, serta sebab konduktivitas molar elektrolit kuat berkurang dengan akar konsentrasi.

Perpindahan muatan⁽¹⁹⁴⁻¹⁹⁶⁾ listrik dapat terjadi apabila terdapat beda potensial antara satu tempat terhadap tempat yang lain, dan arus listrik akan mengalir dari tempat yang memiliki potensial tinggi ke tempat potensial rendah. Di dalam suatu larutan, terjadinya arus listrik dikarenakan adanya ion yang bergerak.

Faktor-faktor yang mempengaruhi kecepatan ion⁽¹⁹⁷⁻²⁰⁰⁾:

1. Berat dan muatan ion, sehingga semakin ringan ion tiap satuan muatan maka semakin cepat ion-ion bergerak
2. Adanya hidrasi, sehingga semakin banyak molekul air yang mengerumuni ion, maka semakin lambat gerakan ion-ion
3. Orientasi atmosfer pelarut disekitar ion-ion
4. Gaya tarik antara ion, sehingga semakin besar gaya tarik ion, maka semakin lambat gerakan ion-ion
5. Temperatur, sehingga semakin tinggi temperature, maka semakin cepat ion-ion bergerak
6. Viskositas, sehingga semakin besar viskositas, maka semakin lambat gerakan ion-ion.

Jika larutan diencerkan maka untuk elektrolit lemah α -nya semakin besar dan untuk elektrolit kuat gaya tarik antar ion semakin kecil. Pada pengenceran tidak terhingga, daya hantar ekivalent elektrolit hanya tergantung pada jenis ionnya. Masing-masing ion mempunyai daya hantar ekivalent yang berbeda. Harga mobilitas ion mempengaruhi nilai konduktivitas dari suatu senyawa, semakin besar tingkat mobilitas ion dalam suatu larutan maka semakin besar pula pengaruh konduktivitas ion dalam hal ini konduktivitas ion dalam senyawa Perak Sulfat⁽¹¹⁻²²⁾.

6. *Konduktivitas*

Konduktivitas merupakan suatu proses pergerakan ion akibat pengaruh medan listrik (E). Hal ini diakibatkan karena adanya suatu pergerakan ion, sehingga larutan dapat menghantarkan listrik. Kemampuan suatu larutan dapat menghantarkan arus listrik disebut dengan konduktivitas listrik. Arus listrik disini dihantarkan oleh ion-ion yang terdapat di dalam suatu larutan, sehingga konduktivitas listrik hanya memperhitungkan konsentrasi ion suatu larutan. Ion-ion memiliki karakteristik dalam menghantarkan arus listrik, maka dari itu konduktivitas listrik hanya menunjukkan konsentrasi ion total suatu larutan. Ion-ion dalam suatu larutan juga dipengaruhi oleh padatan terlarut yang terdapat di dalamnya.

Larutan Perak Sulfat (Ag_2SO_4) juga memiliki nilai konduktivitas. Besarnya nilai konduktivitas disini juga ditentukan oleh jumlah konsentrasi elektrolit. Arus listrik dapat ditransfer melalui materi berupa hantaran yang bermuatan listrik, berwujud arus listrik, sehingga arus memiliki pembawa muatan listrik di dalam di dalam materi dan ada gaya yang dapat menggerakkan muatan tersebut. Pembawa muatan dapat berupa electron atau ion positif dan ion negative dalam larutan elektrolit dan leburan garam. Arus listrik bermuatan bergerak biasanya berasal dari sumber energy listrik. Arus listrik akan mengalir dari tempat yang berpotensi tinggi menuju tempat yang berpotensi lebih rendah. Arus listrik dapat terjadi di dalam suatu larutan karena adanya peran dari ion-ion yang bergerak.

Tabel 3. Konduktivitas Perak Sulfat dalam Berbagai Konsentrasi

Konsentrasi Ag_2SO_4 (% massa)	Konduktivitas ($\text{mS} \cdot \text{cm}^{-1}$)
1%	7,8
2,5%	14,2
3%	22,6
5%	27,3
10%	40,7

Tabel 3. Grafik Konduktivitas Perak Sulfat dalam Berbagai Konsentrasi

7. Viskositas

Viskositas⁽²⁰¹⁻²⁰⁴⁾ merupakan suatu pengukuran dari kekentalan suatu fluida yang diubah baik dengan tekanan maupun tegangan. Dalam kasus ini, metode ini lebih disukai karena peran dari mereaksikan bahan kimia dengan larutan sulfat, akibatnya terjadi suatu penundaan pengerasan. Larutan gel yang tertunda, atau bahan kimia memadat pada waktu yang ditentukan. Larutan ini dapat bervariasi untuk konsentrasi, viskositas⁽²⁰¹⁻²⁰⁴⁾, dan waktu gel untuk padat. Dimana kegunaan dari larutan sulfat ini sebagai perek⁽¹¹⁻²²⁾.

8. Daya Hanyut

Ion perak bersifat netral di dalam air, tahan asam, garam dan berbasa lemah. Stabilitas^(147, 205-207) yang baik terhadap panas dan cahaya. Memiliki daya anti bakteri yang tahan lama, dimana semakin kecil ukuran partikel maka pengaruh gaya gravitasi semakin dapat diabaikan. Lain halnya dengan peningkatan muatan dan kimia permukaan memungkinkan adanya gaya tolak menolak antar partikel dapat terdispersi di dalam air⁽²⁰⁸⁻²¹⁰⁾.

Jika dua buah elektroda yang terpisah dengan jarak berada pada selisih potensial ($\Delta\phi$), maka ion dalam larutan antara kedua elektroda tersebut akan mengalami medan listrik (E) sebesar :

$$E = \frac{\Delta\phi}{l} \dots\dots\dots(1)$$

Untuk ion (muatan ion) mengalami gaya sebesar :

$$F = zeE = \frac{ze\Delta\phi}{l} \dots\dots\dots(2)$$

Kation menuju elektroda negatif, dan anion menuju elektroda positif. Namun saat ion bergerak melalui pelarut maka ion akan mengalami gesekan yang akan memperlambat muatannya yang sebanding dengan kecepatan. Maka dapat disimpulkan gaya perlambatan ini sebagai:

$$F' = fs \qquad f = 6\pi\eta\alpha \dots\dots\dots(3)$$

Kedua gaya ini bekerja dalam arah yang berlawanan dan ion mencapai kecepatan akhir, yaitu kecepatan hanyut ion (s), jika gaya mempercepat F diimbangi oleh gaya perlambatan F . Gaya neto menjadi nol ($F=F$) jika :

$$s = \frac{zeE}{f} \dots \dots \dots (4)$$

Karena kecepatan hanyut mengatur laju transportasi ion, maka dapat dihasilkan konduktivitas berkurang dengan bertambahnya viskositas pelarut ukuran ion. Contohnya, Konduktivitas molar ion logam alkali bertambah dari Li^+ ke Cs^+ , walaupun jari-jari ionnya bertambah⁽²¹¹⁻²¹⁴⁾. Radius α dalam rumus stokes adalah radius hidrodinamik ion yaitu radius efektif dalam larutan dengan memperhitungkan molekul H_2O yang dibawa dalam bola hidrasi. Ion kecil menyebabkan medan listrik lebih kuat dari pada ion besar, sehingga ion kecil lebih mudah terlarut secara ekstensif dari ion besar. Jadi, ion dengan radius kecil dapat mempunyai radius hidrodinamik besar, karena ion itu menyeret banyak molekul pelarut melalui larutan itu saat bermigrasi⁽²¹⁵⁻²¹⁷⁾.

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

x = jarak (m)

t = waktu (dt)

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

$$E = \frac{dE}{dx} \dots \dots \dots (6)$$

Maka,

$$U = \frac{\lambda_m}{zF} \dots \dots \dots (7)$$

Z = valensi kation

F = Faraday

Karena kecepatan hanyut mengatur laju transportasi ion, maka di harapkan konduktivitas akan berkurang dengan bertambahnya viskositas pelarut akan ukuran ion.

Perhitungan kecepatan hanyut :

Pemisalan Jika potensial Ag_2SO_4 3,61 V dan jarak antara elektroda adalah 1,5 cm, maka kecepatan hanyutnya dapat dihitung sebagai berikut :

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

$$E = \frac{3,61 \text{ V}}{1,5 \text{ cm}} = 2,407 \text{ V/cm}$$

Jadi kecepatan hanyut Ag_2SO_4 adalah 2,407 V/cm

8. Besaran KF_3

1. Bilangan Transport

Bilangan transport merupakan fraksi dari arus total yang dibawa oleh ion jenis tertentu, untuk larutan dengan 2 jenis ion, bilangan dengan I^+ merupakan arus kation, I adalah arus total yang melalui larutan, dan I^- adalah arus anion. Dapat diasumsikan sebagai:

$$I^+ + I^- = I$$

Bilangan transport merupakan pembatas t^0 , namun untuk limit konsentrasi nol dari larutan elektrolit itu. Arus yang berasal dari setiap jenis ion berhubungan dengan mobilitas ion⁽⁸⁸⁻⁹¹⁾.

Jadi hubungan antara t^0 dan u yaitu:

$$t^0 = \frac{z v u}{\sum_i z v u_i} \dots \dots \dots (9)$$

Untuk elektrolit simetris merupakan bilangan muatan untuk kedua ion sama, maka persamaan diatas dapat disederhanakan:

$$t^0 = \frac{u}{\sum_i u_i} \dots \dots \dots (10)$$

Hubungan antara konduktivitas ion dengan mobilitas ion⁽⁸⁸⁻⁹¹⁾:

$$t^0 = \frac{v\lambda}{\sum_i v_i \lambda_i} = \frac{v\lambda}{\Lambda_m^0} \dots \dots \dots (11)$$

Jadi untuk setiap jenis ion:

$$v\lambda = t^0 \Lambda_m^0 \dots \dots \dots (12)$$

2) Hubungan Einstein

Hukum Fick⁽⁹⁶⁻¹⁰¹⁾ untuk fluks partikel dalam mol molekul per satuan luas per satuan waktu adalah:

$$J = -D \frac{dc}{dx} \dots \dots \dots (13)$$

Dengan D merupakan koefisien difusi dan $\frac{dc}{dx}$ merupakan kemiringan dari konsentrasi molar. Fluks partikel berhubungan dengan kecepatan hanyut dengan:

$$J = sc \dots \dots \dots (14)$$

Hubungan ini merupakan kelanjutan dari argument sebelumnya. Jadi, semua partikel dalam jarak $s\Delta_t$ A, dapat melewati jendela dengan luas A dalam selang waktu Δ_t . Dengan demikian, jumlah mol dapat lewat dalam selang waktu tersebut adalah: $s\Delta_t \times c$, sehingga:

$$Sc = -D \frac{dc}{dx} \dots \dots \dots (15)$$

Jika sekarang kita menyatakan $\frac{dc}{dx}$ dalam ϵ , menggunakan persamaan 15, maka diperoleh:

$$S = -\frac{D}{c} \frac{dc}{dx} = \frac{D}{RT} \times \epsilon \dots \dots \dots (16)$$

Terdapat satu kasus ketika kita sudah mengetahui kecepatan hanyut dan gaya efektif yang bekerja pada partikel:

Dimana 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. Jadi penggantian nilai tersebut ke dalam persamaan di atas, menghasilkan:

$$\mu E = \frac{D}{RT} \times zFE \text{ atau } \mu = \frac{zFD}{RT} \dots \dots \dots (17)$$

$$D = \frac{\mu RT}{zF} \dots \dots \dots (18)$$

Persamaan ini tertata ulang menjadi hasil yang sangat penting, yang dikenal sebagai **hubungan Einstein**, antara oefisien difusi dengan mobilitas ion⁽⁸⁸⁻⁹¹⁾.

4. Kesimpulan

Molekul Ag_2SO_4 mengalami interaksi dengan air. Proses interaksi mempengaruhi jarak atom yang berikatan dan sudut ikatan, dibuktikan dengan terjadinya perubahan nilai setelah molekul di optimasi. Molekul perak sulfat dioptimasi, dengan jarak O-S adalah 1.660 Å dan jarak antara atom Ag-O adalah 1.980 Å. Selain energi, proses interaksi antara molekul dengan air juga dipengaruhi oleh muatan dan medan gaya antar molekul yang berpengaruh terhadap jarak dari masing-masing atom yang berpengaruh terhadap tarikan antar molekul yang berinteraksi. Hasil penelitian konduktivitas larutan Ag_2SO_4 semakin meningkat seiring dengan kenaikan konsentrasi persen massa sesuai grafik hasil perhitungan. Energi optimasi MM2 Minimization, Optimasi MM2 Dynamics, dan Optimasi MM2 Properties berturut-turut yaitu 210. 2194 kcal/mol, 755. 377 kcal/mol, 216. 774 kcal/mol. Nilai kecepatan hanyut Perak Sulfat (Ag_2SO_4) dengan potensial 3,61 V dan jarak antara elektroda adalah 1,5 cm adalah 2, 407 V/ cm.

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