

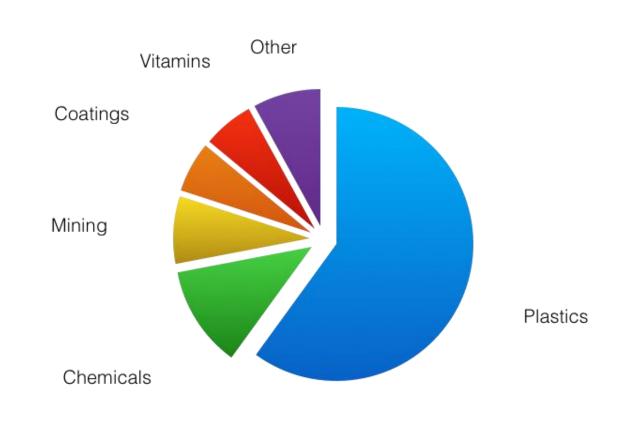
Cyanide Analysis:

Cyanide Chemistry,
Methodology, Interferences,
Sample Handling and
Regulatory Updates

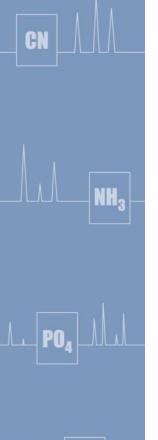




Distribution of the Industrial Uses of CN

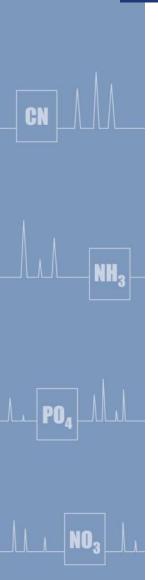








Who is measuring cyanide?



- NPDES
- Pretreatment
- SDWA
- Industrial hygiene
- Foods
- Beverages
- Mining
- Manufacturing



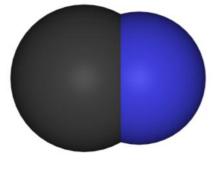


A generalized summary of cyanide and it's metal

- cyanide species



- Transition metals strong bonds
- Alkali metals ionic bonds



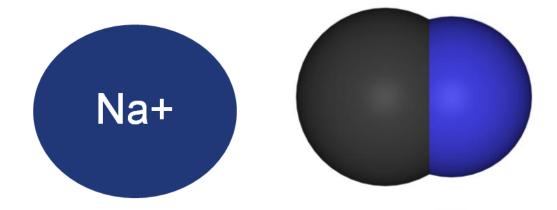






Free Cyanide is the CN ion and HCN, generate HCN at pH 6

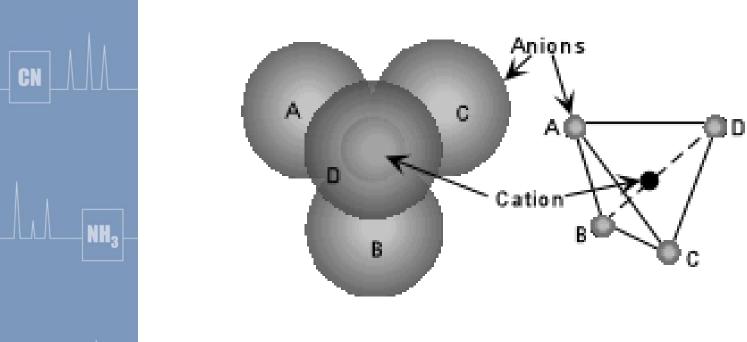








Metal Complexes require acid to generate HCN

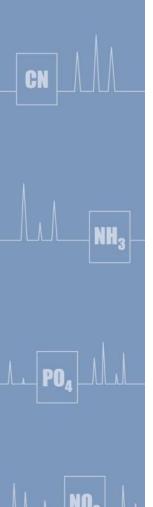


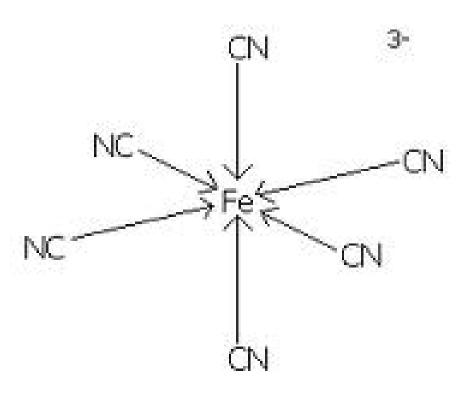






Strong Metal Complexes are stable in acid solution









Iron Cyanide Complexes are very stable in the environment



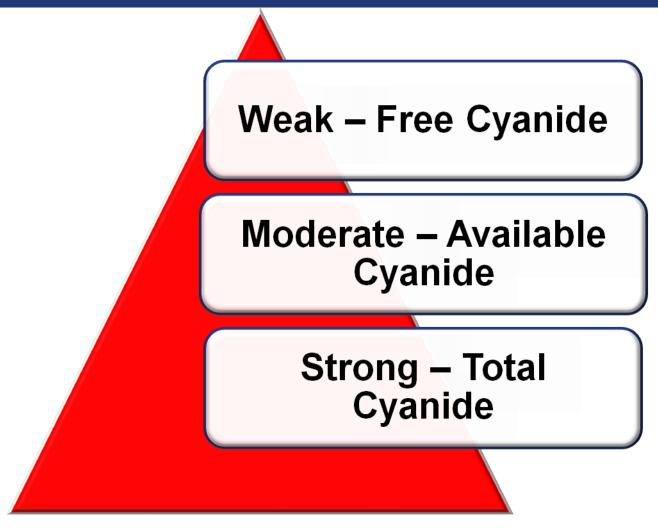








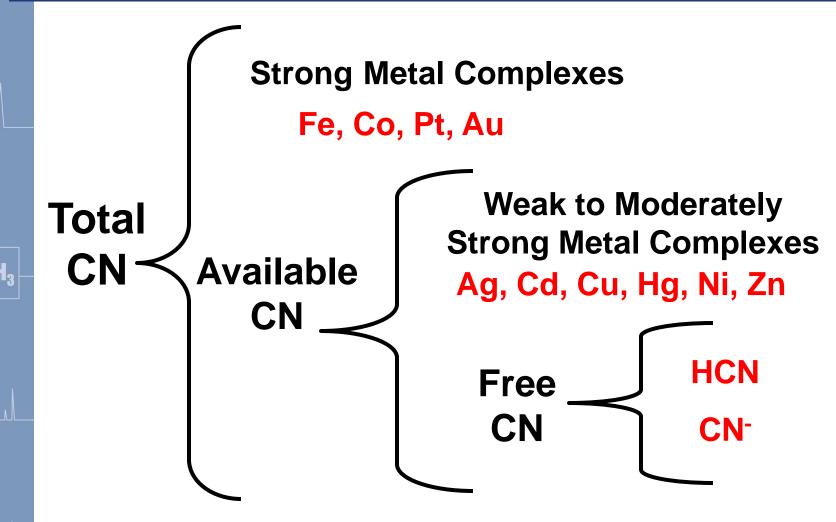
Toxicity of Cyanide Complexes is related to its ability to produce HCN







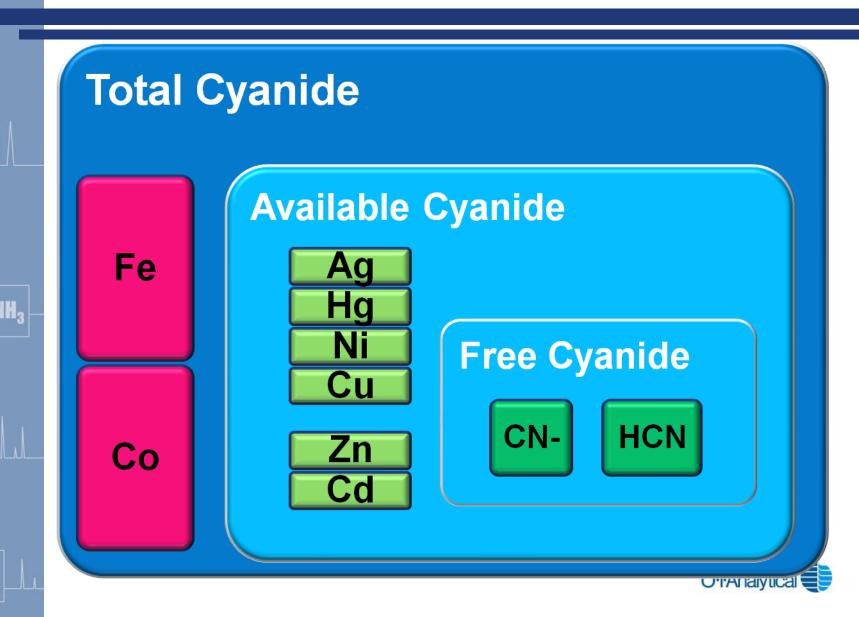
Cyanide methods measure the various cyanide "species"







Cyanide methods measure the various cyanide "species"











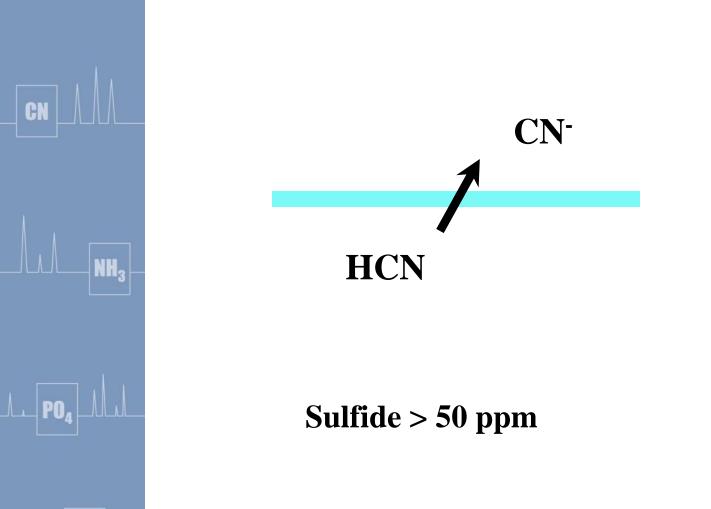


How Do You Measure Cyanide?





Gas diffusion - Amperometry



Membrane



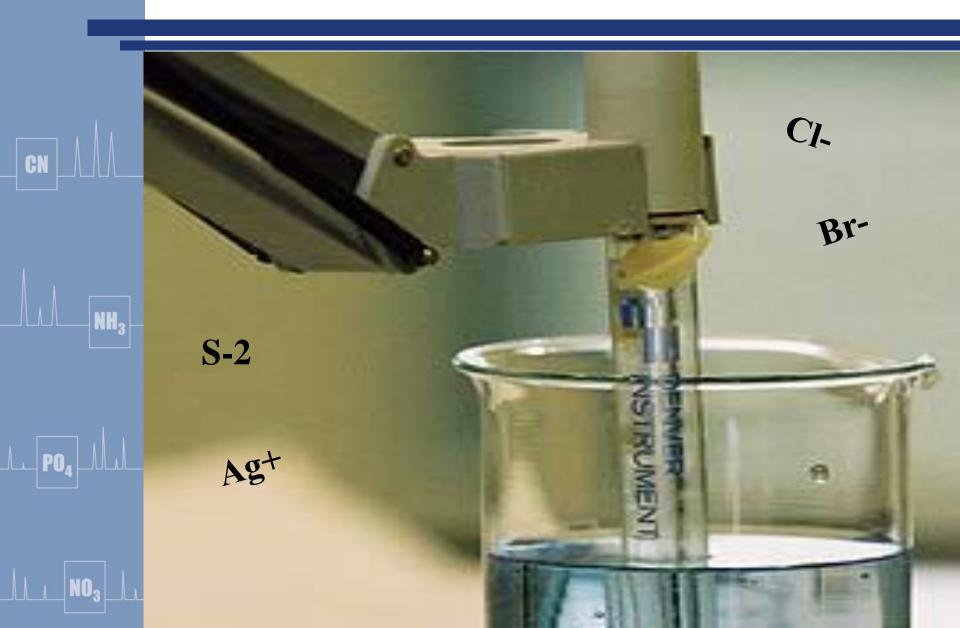


Titration by silver ion



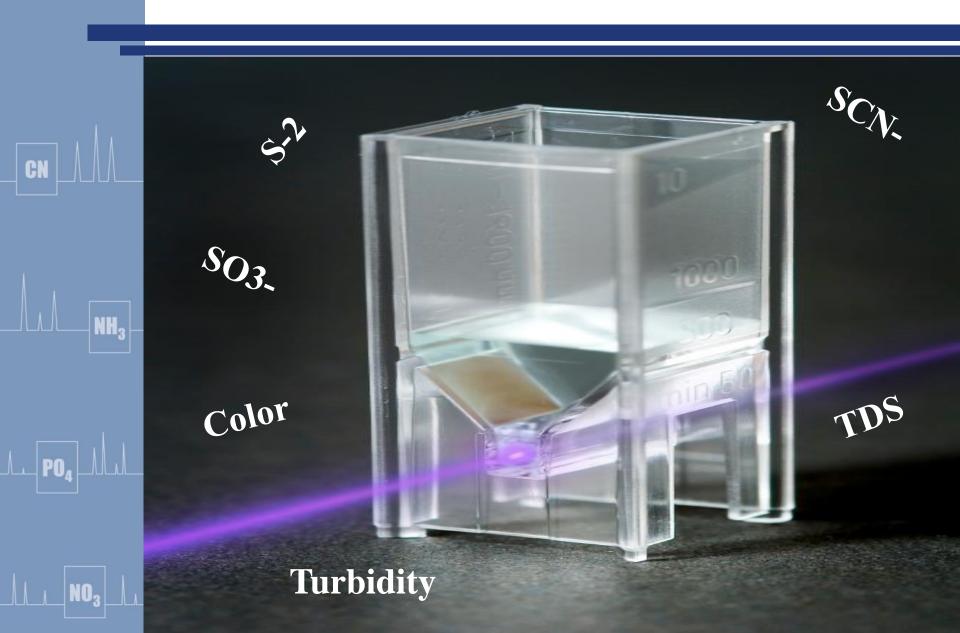


Ion Selective Electrode (ISE)





Colorimetric methods

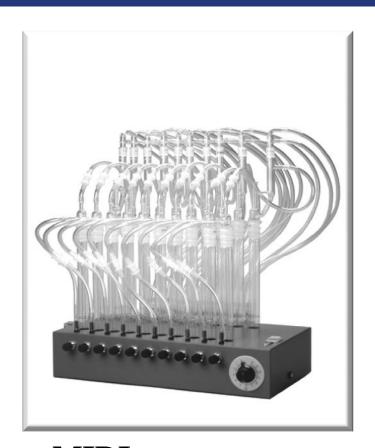




Manual "distillation" is used to dissociate as HCN



Macro Distillation



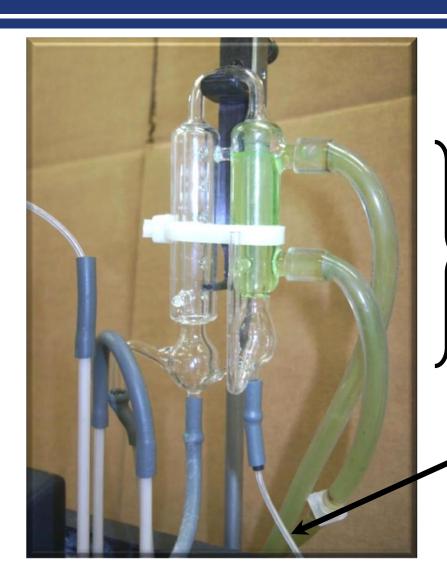
MIDI Distillations







Distillation can be automated on a continuous flow analyzer



Distillation and condenser

Distillate







Cyanide Methods







Cyanide methods require separation of CN from matrix



 Separated from interferences, cyanide measurement is no different than running standards.









APPROVED METHODS

Free CN	GD-	ASTM D7237
TIEC CIV	Amperometry	
WAD CN	Distillation/	ASTM D2036 or
WAD CN	Colorimetry	SM4500
CATC	Distillation/	ASTM D2036 or
CAIC	Colorimetry	SM4500
Available CN	GD-	OIA 1677 or
Available CN	Amperometry	ASTM D6888







Unlike colorimetry, GD amperometry is easy to visualize



- CN⁻ + H⁺ → HCN
- HCN + OH \rightarrow CN \rightarrow + H2O
- Ag + 2CN \rightarrow Ag(CN)₂ \rightarrow + e⁻



measure













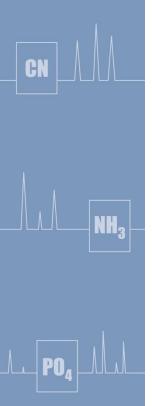


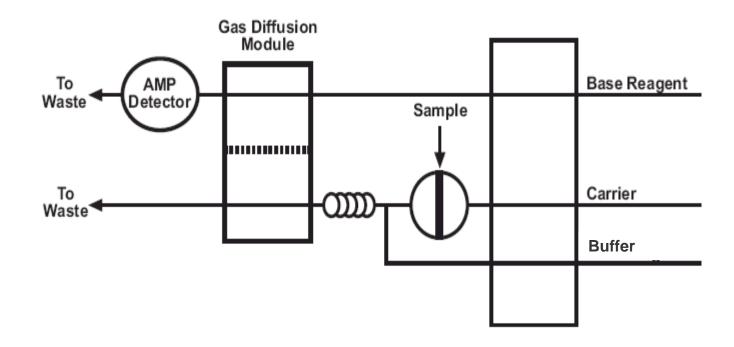
Aquatic Free Cyanide Analysis





ASTM D7237-06 can be run on a OIA1677 CNSolution analyzer





Same Cartridge as OIA 1677





WAD Cyanide methods measure "available cyanide"



Method Number	Description Measureme		
SM 4500-CN I	Buffered pH 4.5 manual Distillation	Colorimetry	
ASTM D 2036	Buffered pH 4.5 manual distillation	Colorimetry, Gas Diffusion - Amperometry	













Available Cyanide Analysis





WAD Cyanide methods measure "available cyanide"



Method Number	Description Measureme		
SM 4500-CN I	Buffered pH 4.5 manual Distillation	Colorimetry	
ASTM D 2036	Buffered pH 4.5 manual distillation	Colorimetry, Gas Diffusion - Amperometry	





Ligand Exchange methods measure available cyanide

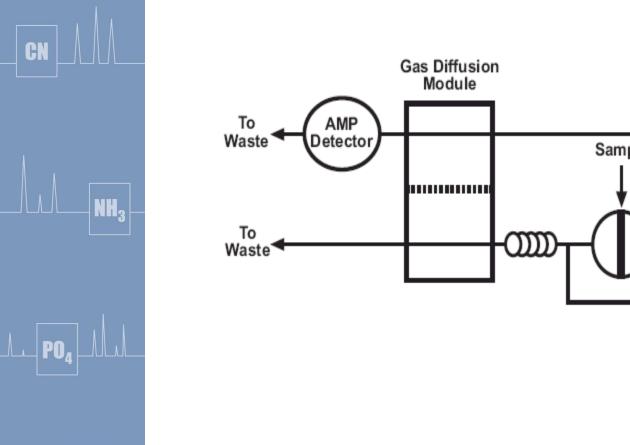
Method Number	Description	Measurement	
OIA 1677	Ligand Exchange / Flow Injection Analysis	Gas Diffusion - Amperometry	
ASTM D 6888	Ligand Exchange / Flow Injection Analysis	Gas Diffusion - Amperometry	

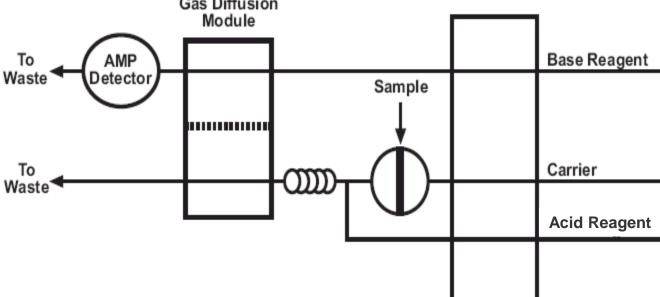
GD-amperometry methods do not require distillation





OIA 1677 or ASTM D6888 flow diagram









Ligand Exchange GD-amperometry methods have fewer interferences

CATC	WAD	OIA 1677	
N-organics	Excessive Iron Cyanide	None	
SCN,NH ₃ ,NO ₂	Concentration Dependent		
S ₂ O ₃ , H ₂ O ₂			
Concentration Dependent			







Ligand Exchange GD-amperometry methods provide the best benefits



- No distillation (eliminates 1 4 hours preliminary sample treatment)
- Low MDL (0.5 ppb)
- No Interferences
- High Throughput (up to 90 samples per hour)
- Ease of Operation, very simple chemistry.













Total Cyanide Methods

Automated gas diffusion distillation and nondistillation methods





Total Cyanide Methods – Manual Distillation

Method Nu	mber	Description	Measurement	
SM 4500-C	N C	Manual Macro Distillation – Mg Cl ₂	Manual colorimetry / ISE	
ASTM D 2	036	Manual Macro Distillation – MgCl ₂	Manual colorimetry, ISE, GD-amperometry, IC	
EPA 335.	4	Midi Distillation – MgCl ₂	Automated Colorimetry	
ASTM D 7	284	Midi / Micro Distillation – MgCl ₂	Gas Diffusion - Amperometry	







Automated total cyanide methods use UV to liberate HCN from Fe

	Descriptive Name	Method Number	Description	Measurement
	Total Cyanide	ASTM D4374 (Kelada 01)	High power UV- Auto distillation Alkaline pH	Automated colorimetry
		EPA 335.3	Low power UV- Auto distillation pH <2	Automated Colorimetry
		OIA 1678/ASTM D7511	Low power UV- pH <2	Gas Diffusion - Amperometry







Comparison of Kelada and OIA 1678

	Kelada 01	ASTM D7511
Pump Tubes	15	5
Reagents	Pyridine	No Pyridine
Distillation	Yes	No
SCN Interaction	0.25 – 0.5 %	0.01 – 0.03 %





Comparison of Total CN methods

	335.4	ASTM D7284	ASTM D7511
Sample Preparation	2 – 3 hour distillation	1 – 3 hour distillation	No distillation
Analysis	1 – 2 minutes	1 – 2 minutes	1-2 minutes
Total Time	3-4 hours	2 – 4 hours	1-2 minutes



Advantages - CNSolution 3100

	Distillation/ Colorimetry	EPA 335.4	
Total Cyanide	Distillation / GD- Amperometry	ASTM D7284	
	No Distillation / GD-Amperometry	OIA 1678 (ASTM D7511-09)	

One Instrument – multiple methods







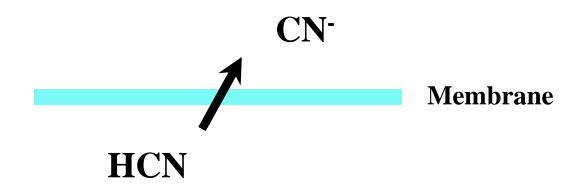
How do you solve interference problems caused by distillation?





Replace distillation with gas diffusion





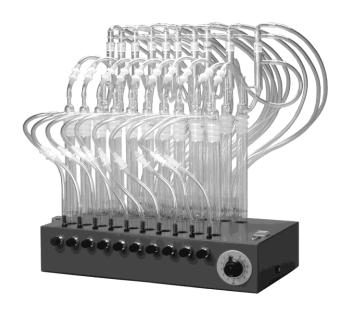




Distillation most common technique to remove interference



Macro Distillation



MIDI Distillations

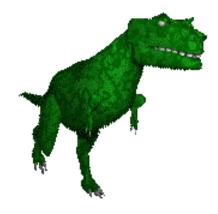






Many cyanide interferences result from distillation

- Destroy CN
- Create CN
- UV distillation colorimetry worst









Distillation actually creates CN interferences

- Boiling acid
- Automated UV-Distillation
 - Boiling acid







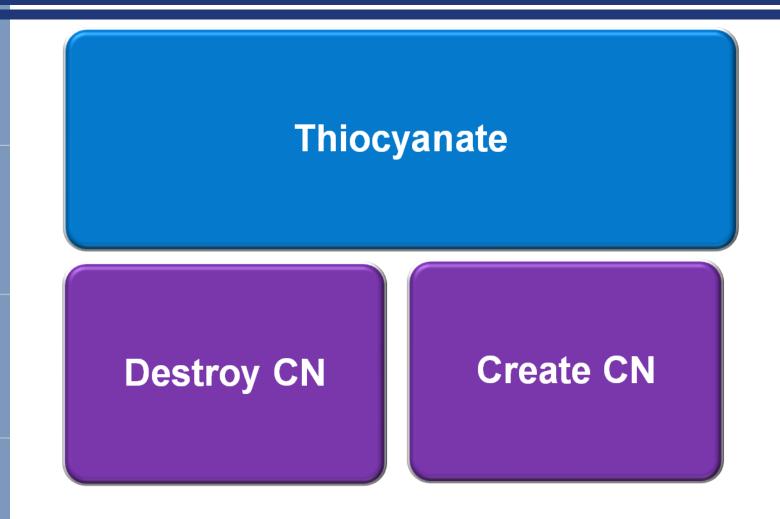








Interferences -







Thiosulfate reacts with cyanide during distillation



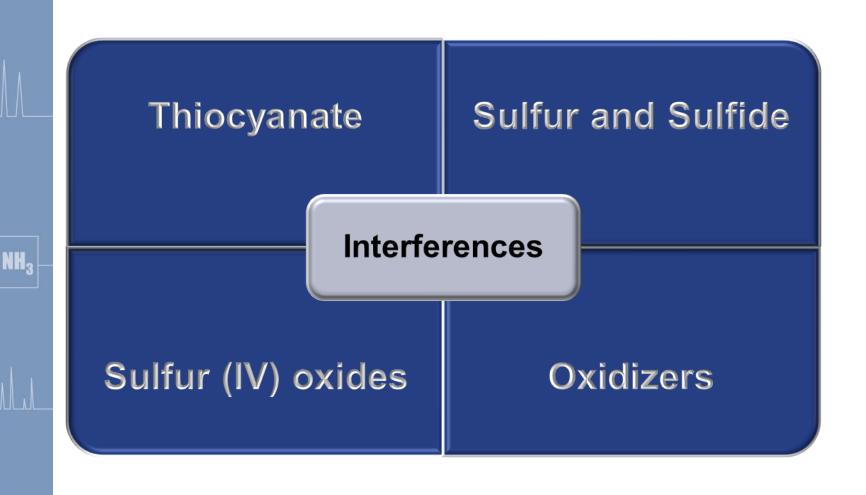
- 0.200 mg/L $CN^- + 200$ mg/L $S_2O_3^{-2}$
 - Cyanide Found = 0.160 mg/L
 - Recovery = 80%*
 - * Double Chloramine T added, or recovery would be lower.







These compounds are in almost every sample and interfere significantly







Thiocyanate + Nitrate results in positive bias

- The addition of Sulfamic acid does not sufficiently reduce this interference.
 - A real POTW sample with 0.1 mg/L SCNand 63.5 mg/L NO₃⁻ detected total CN⁻ at 0.10 mg/L even after the addition of Sulfamic Acid



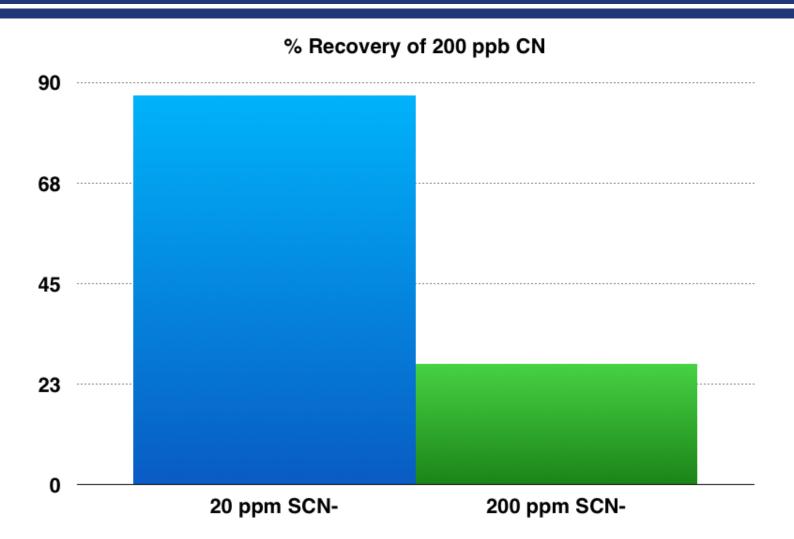








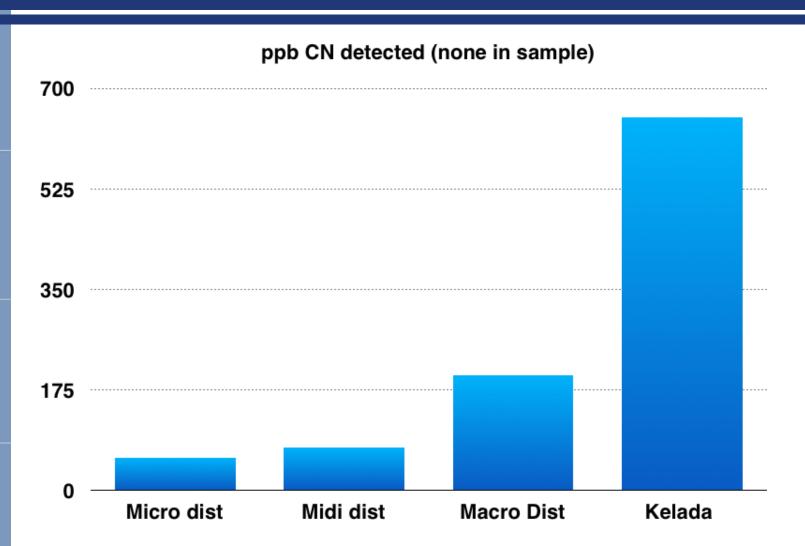
Interferences – Thiocyanate







Interferences – Thiocyanate and Nitrate







Sulfite reacts rapidly with CN in basic solutions



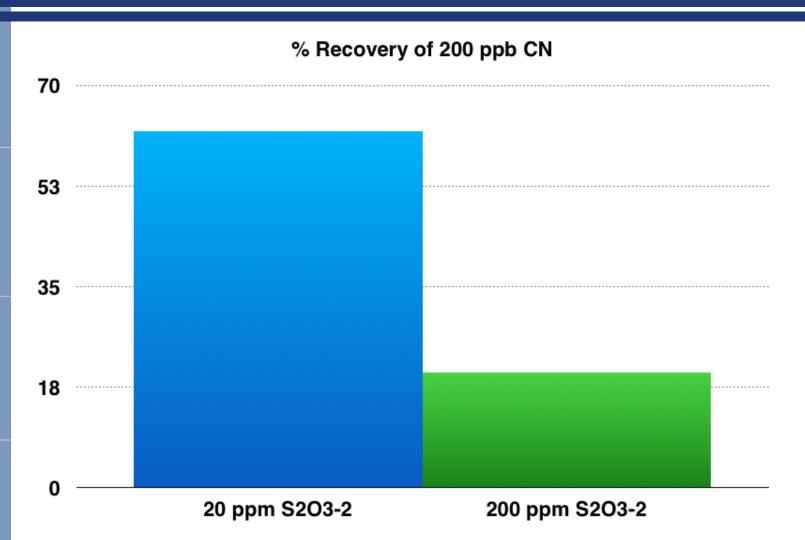
- $0.200 \text{ mg/L CN}^- + 200 \text{ mg/L SO}_3^{-2}$
 - Cyanide Found = 0.000 mg/L
 - Recovery = 0%
- This reaction occurs in absorber solution, or in preserved sample







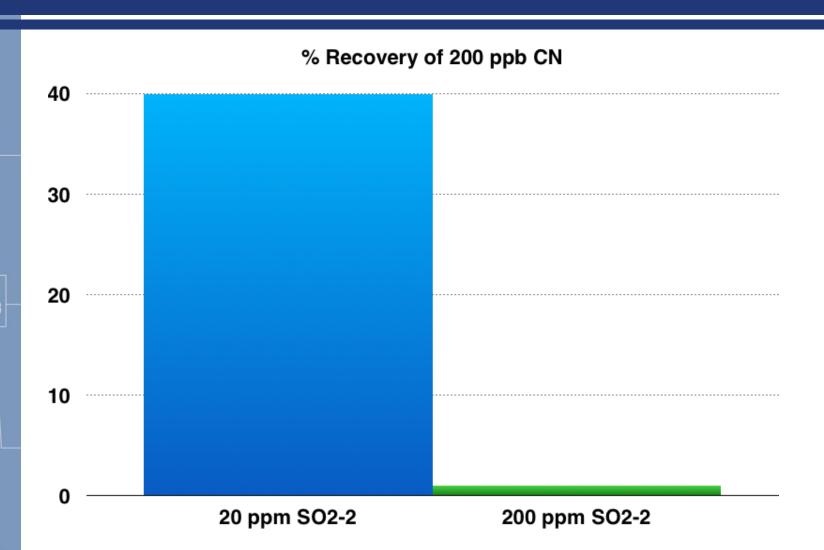
Interferences - Thiosulfate







Interferences - Sulfite







Interferences – Sulfur Compounds

- No Spot Tests
- Dechlorination









Sulfur compounds react rapidly with CN



$$-8CN^- + S_8 \rightarrow SCN^-$$

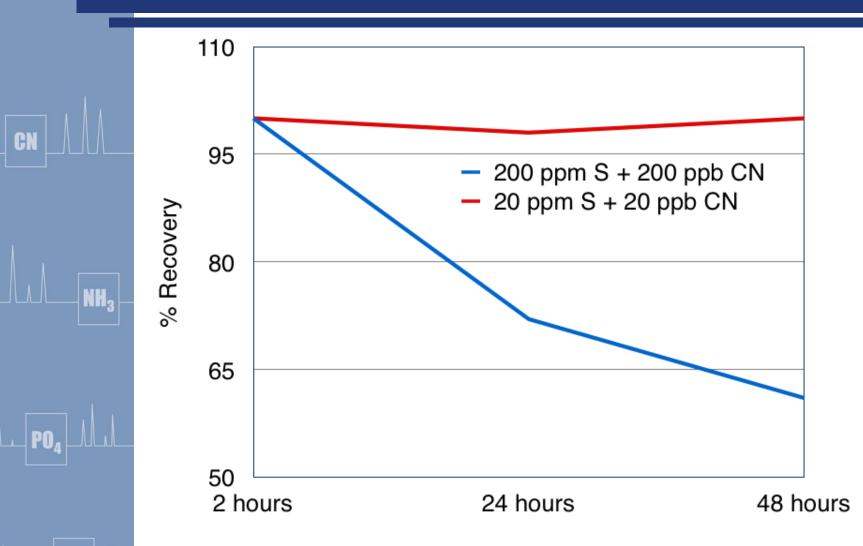
- Metal Sulfides
 - Cu₂S, FeS, PbS, CuFeS₂, CdS, ZnS, etc.
 - S reacts with CN⁻ to form SCN⁻







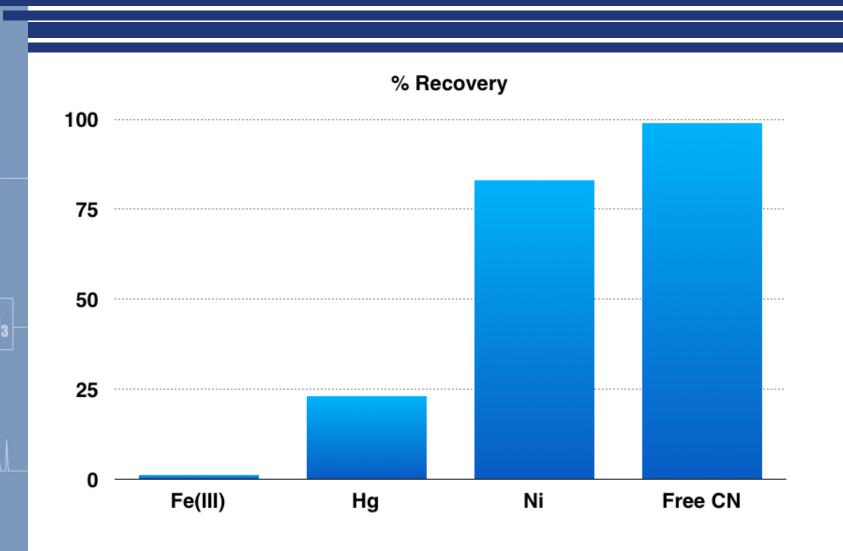
Holding Time Study – Sulfide Bearing Samples







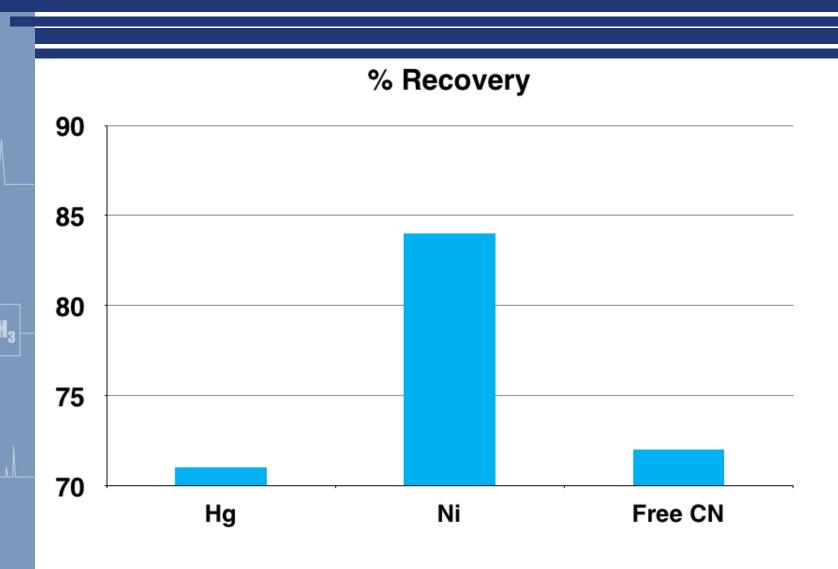
Cannot use Cadmium to Treat Sulfide







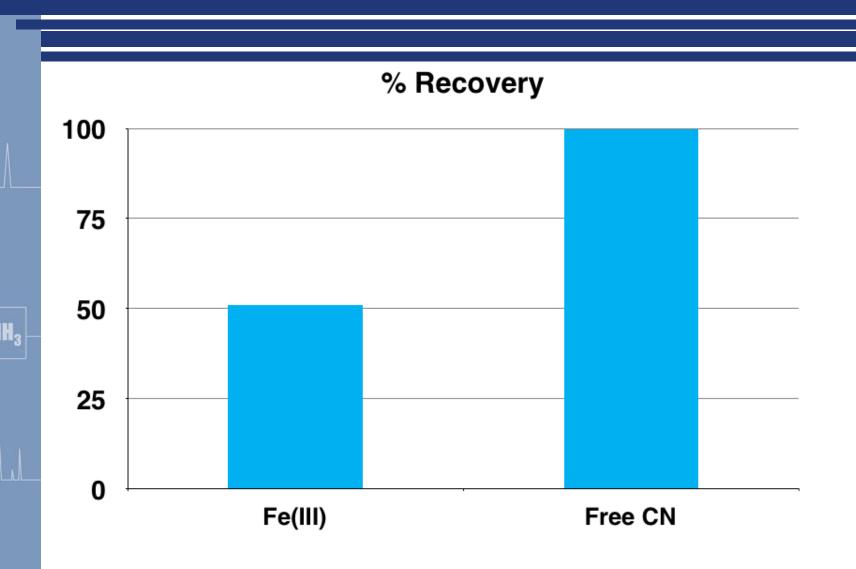
Headspace to Treat Sulfide







Bismuth to Treat Sulfide then distillation





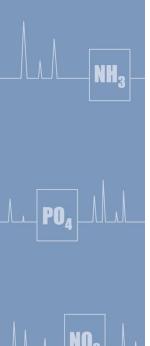


Oxidizers destroy cyanide before or during distillation



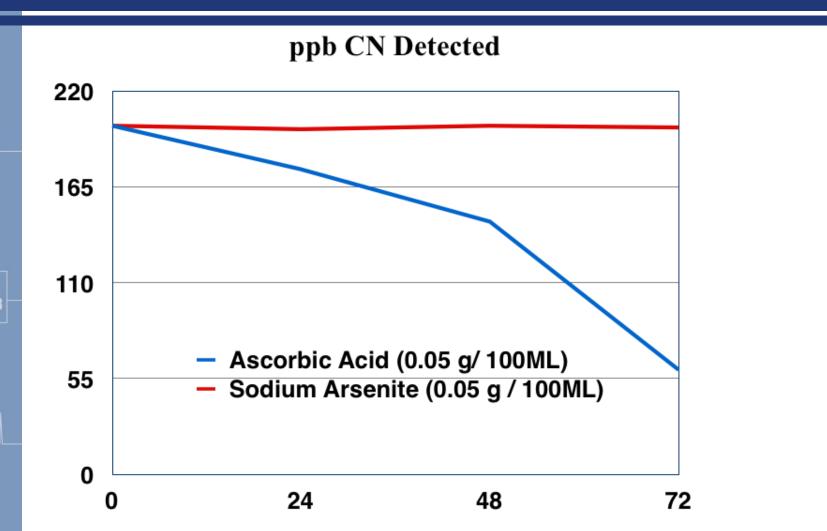
- Hypochlorite
- Peroxide
- Caro's Acid
- Chloramines







Oxidizer Removal



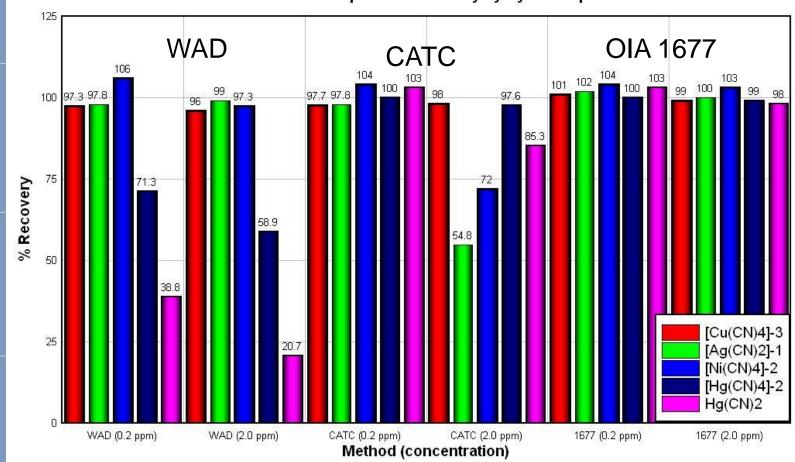






Ligand Exchange GD-amperometry methods get better recovery

Comparison of Recoveries by Available Cyanide Methods
Concentration Dependent Recovery by Cyanide Species







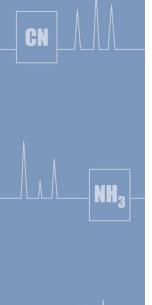


Cyanide methods that utilize distillation have significant disadvantages

Time Consuming

- One hour long distillation (does not take into account setup and teardown)
- CATC requires two, one hour distillations
- Bulky and Relatively Expensive Glassware
- Operator-dependent results (technique)
- Multiple Interferences

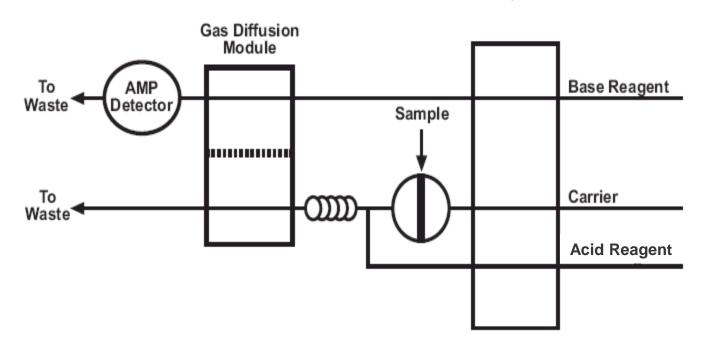






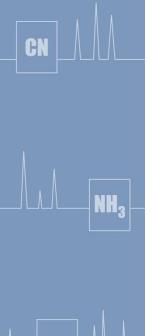
GD-amperometry provides the safest, easiest, and most accurate technique

No pyridine



ASTM D7284-08 is a "green" chemistry









CNSolution 3100

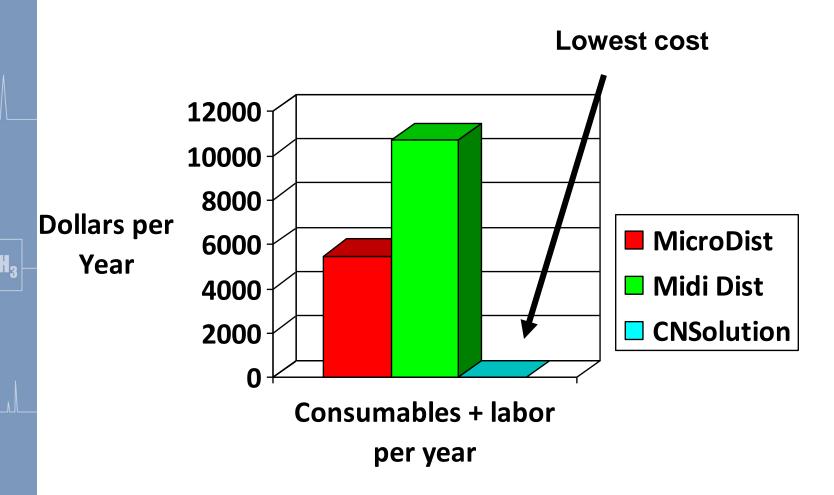
- Rapidly Analyze Cyanide with Confidence in Results
 - Free Cyanide
 - Available Cyanide
 - Total Cyanide
- Eliminate Time Consuming, Error Causing Distillations
- Expand Capability to Colorimetric FIA and SFA







Gas diffusion eliminates distillation and associated cost

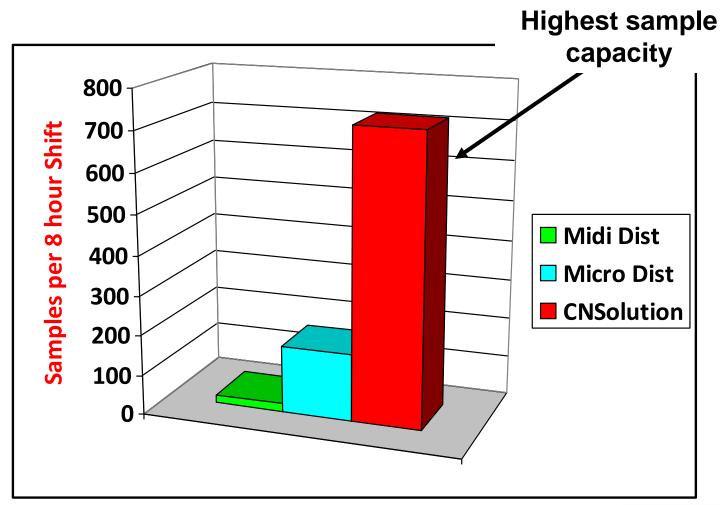








Eliminating distillation increases laboratory capacity



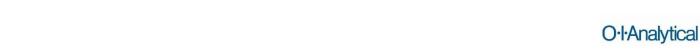






Ligand Exchange GD-amperometry methods give you results in minutes

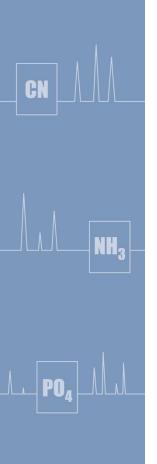
		CATC	WAD	OIA 1677
	Sample Preparation	2 distillations 2 – 3 hours	1 distillation 2 – 3 hours	No distillation
	Analysis	1 – 2 minutes	1 – 2 minutes	1 – 2 minutes
	Total Time	3 – 4 hours	3 – 4 hours	1 – 2 minutes

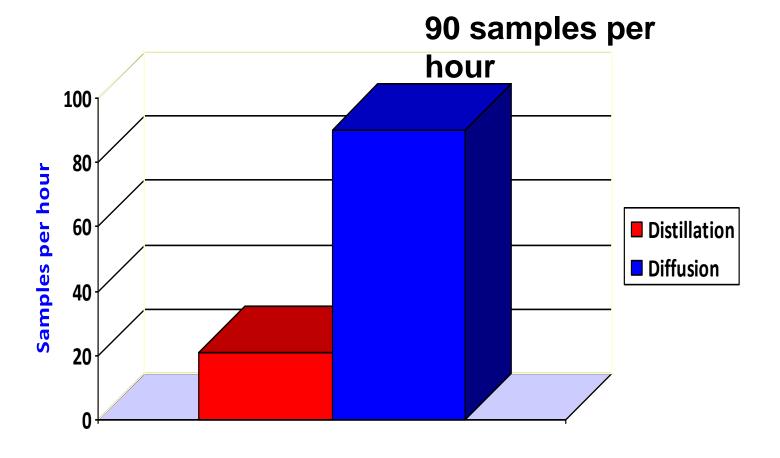






Ligand Exchange GD-amperometry methods means more samples







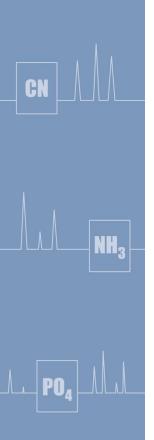


The CNSolution is your solution to cyanide analysis

Gas diffusion amperometry methods:

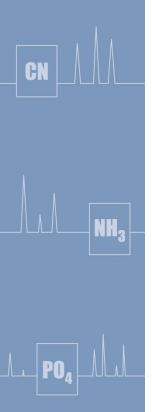
- Save time
- Save money
- Are more accurate
- Have fewer interferences
- Are "green"
- The CNSolution = the FS3100
 - Change to a photometric detector and run any colorimetric chemistry

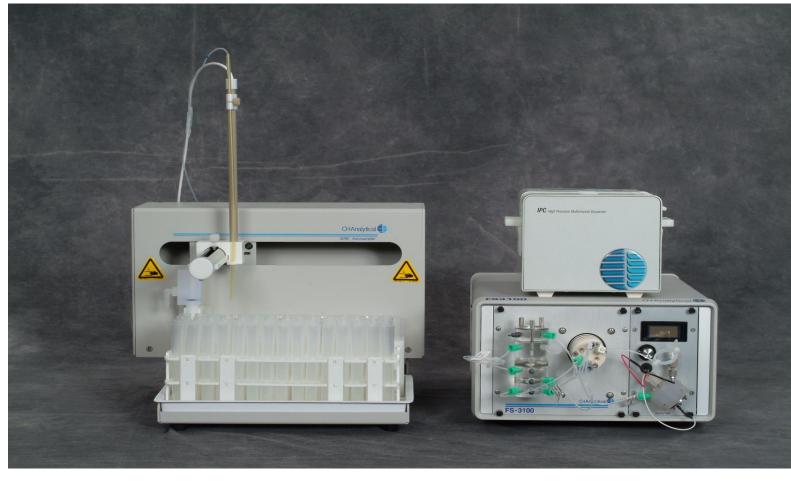






The CNSolution 3100 available cyanide system



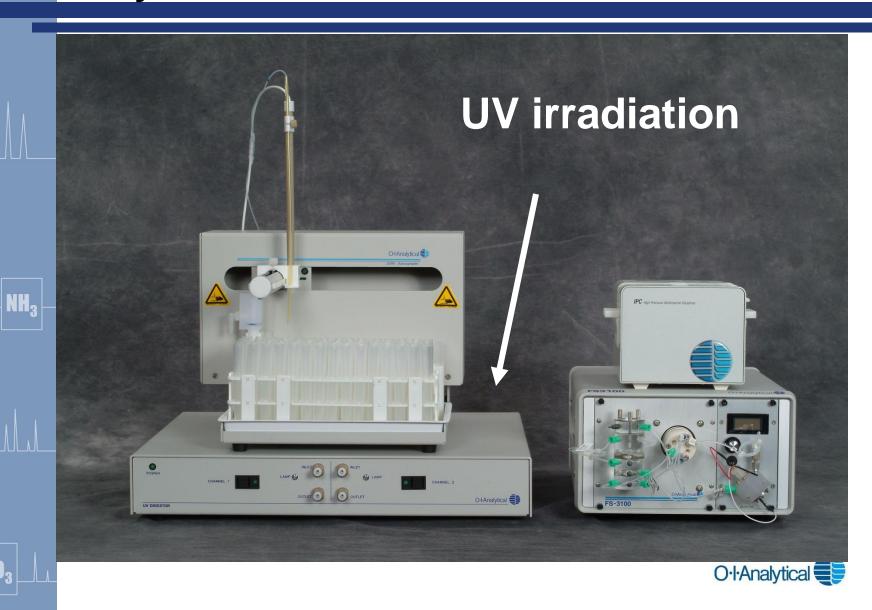






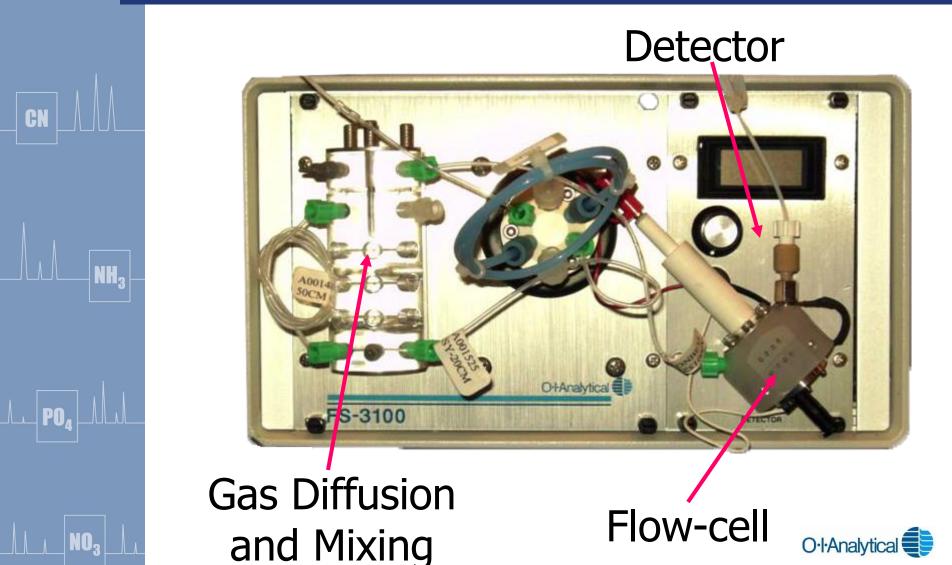


The CNSolution 3100 total cyanide system





OIA 1677 - CNSolution





Flow Solution 3100

- Flow Injection Analyzer
 - Colorimetric detector added it becomes the FS 3100 FIA analyzer
 - All FS 3100 methods
 - NO_3 -N
 - NH_3-N
 - PO₄
 - TKN



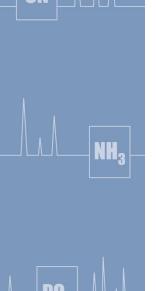


A high quality peristaltic pump



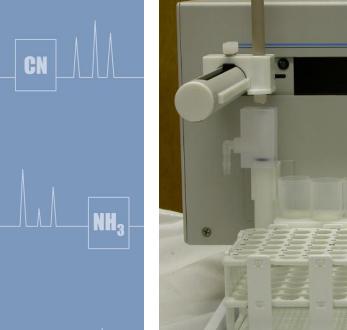
Separate module, individual channels, long pump tube life.







A random access xyz sampler





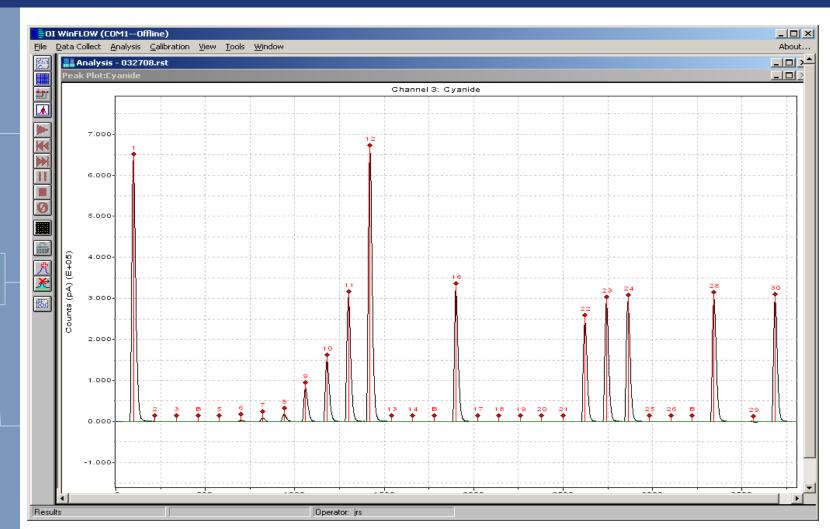
- Integrated circulating wash station
- 90 or 360 positions
- Separate standard and QC vials







Winflow software provide accurate quantitation of CN results







The CNSolution 3100 is accurate, and cost effective

- NH₃

PO₄



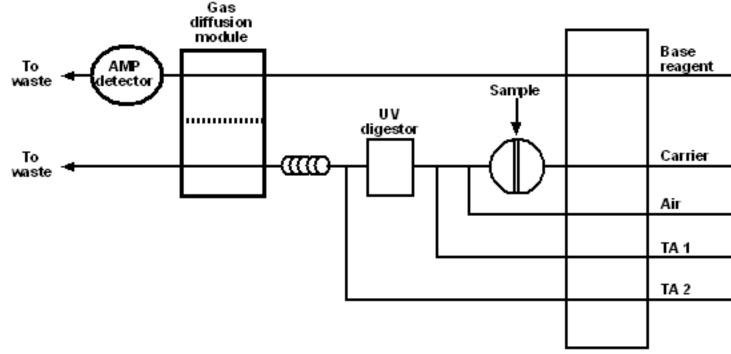
- Rapidly analyze cyanide
- Eliminate time consuming error causing distillations
- Expand capability to colorimetric FIA and SFA





ASTM D7511 is easy to understand and operate and does not distill.

No pyridine



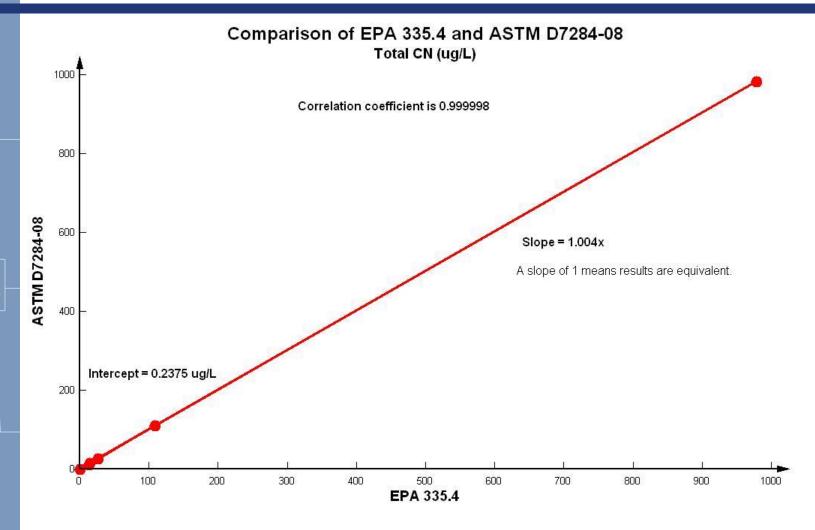
"Green" Chemistry







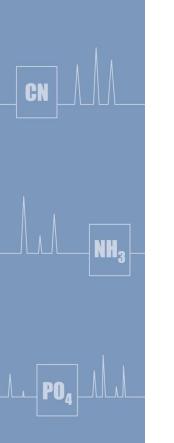
GD-Amperometry Equivalent to Colorimetry

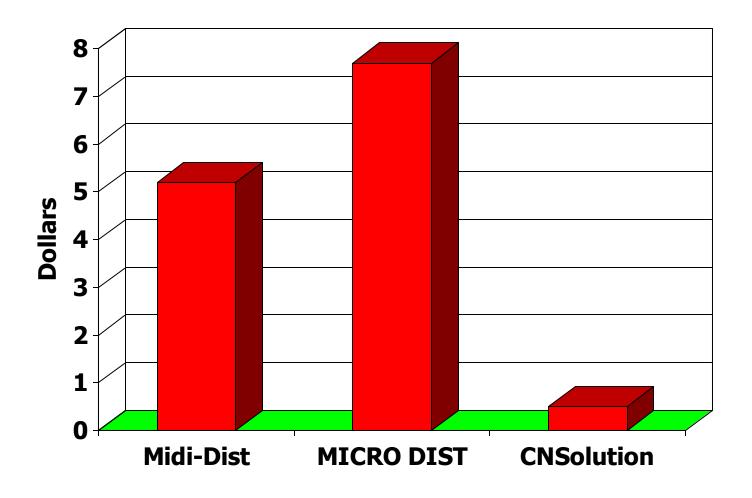






Estimated Reagent and Consumable Cost per Analysis for Distillation (US Dollars)

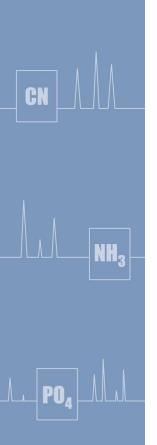


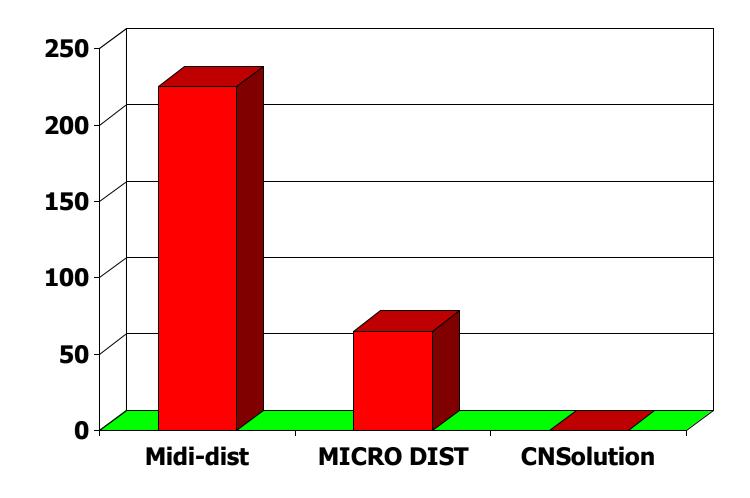






Estimated Labor (in minutes) Required to Distill 20 Samples for Analysis

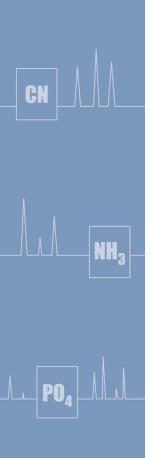


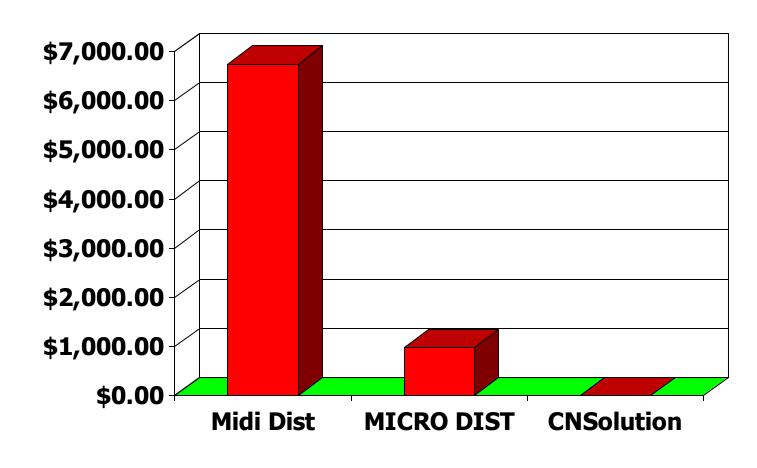






Estimated Annual Labor Cost to Distill and Analyze 40 Samples per Month (Including Overhead)



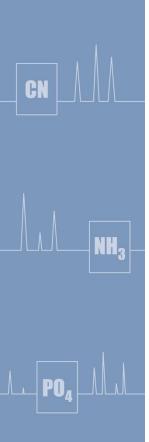


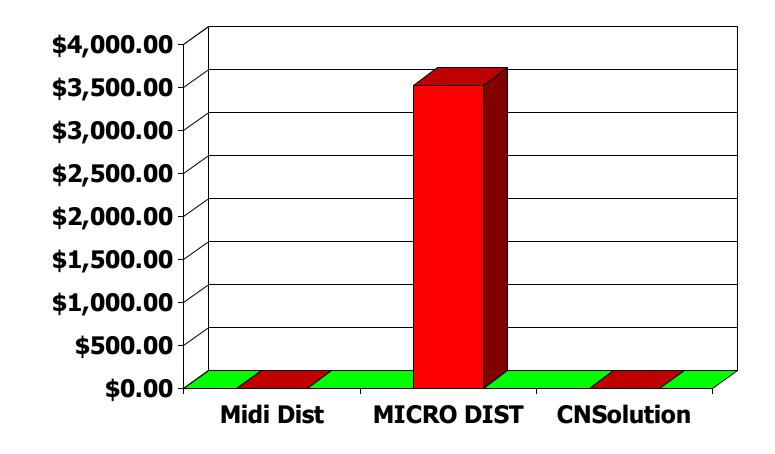
Assume tech pay at \$15/hour





Estimated Annual Cost for Consumables to Distill and Analyze 40 Samples per Month

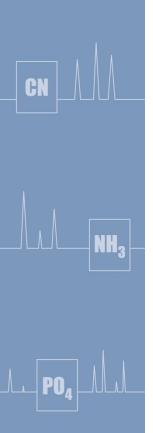


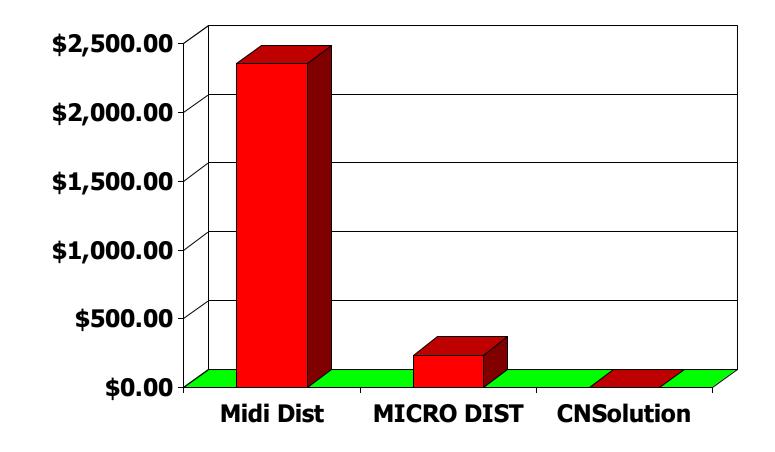






Estimated Annual Cost for Reagents to Distill and Analyze 40 Samples per Month

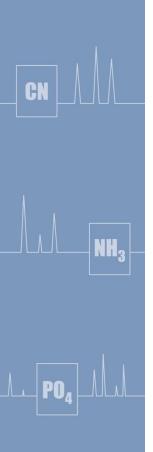


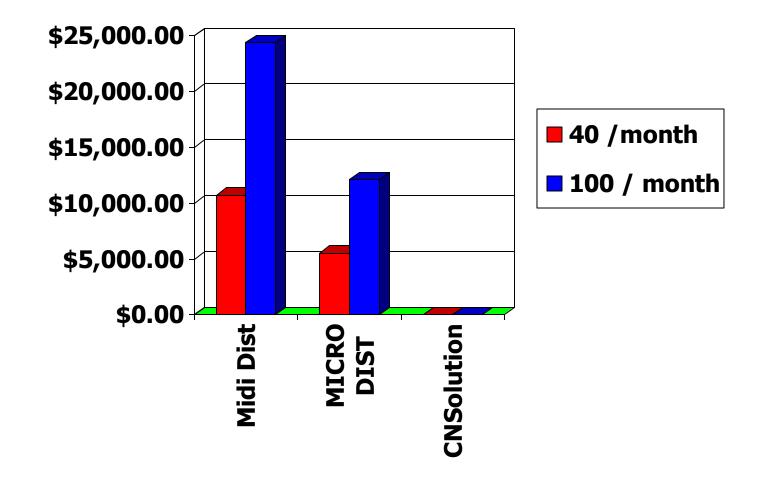






Annual Cost for Distillation vs. Non-Distillation Techniques

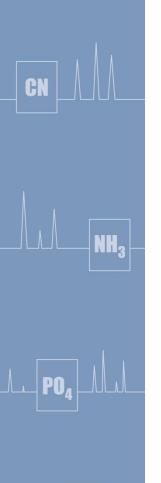


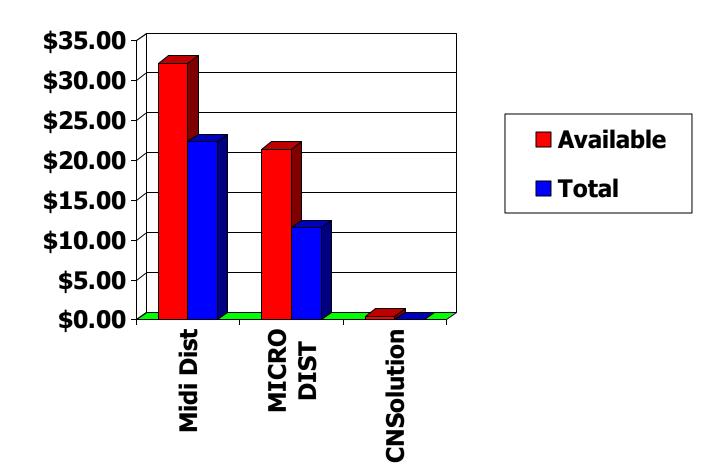






Comparison of Cost per Sample by Cyanide Species and Method

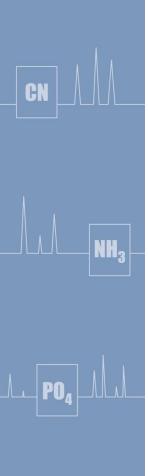


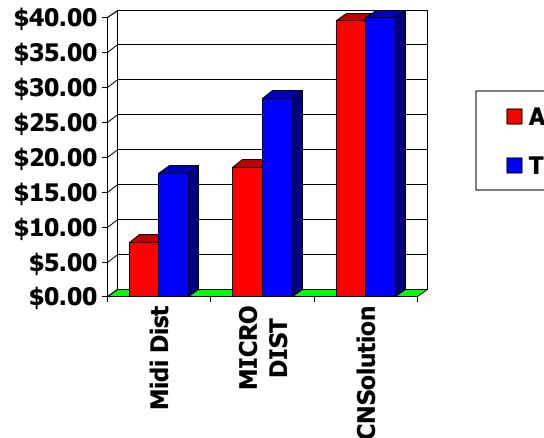






Profit per Sample by Cyanide Species at \$40 per Test



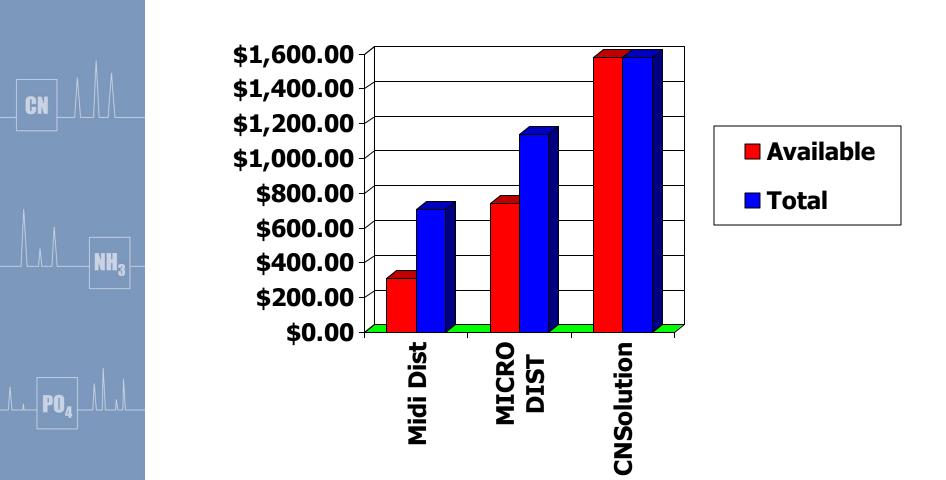








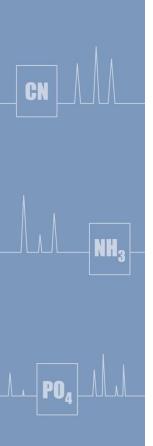
Profit per Month by Cyanide Species at \$40 per Test and 40 Samples per Month

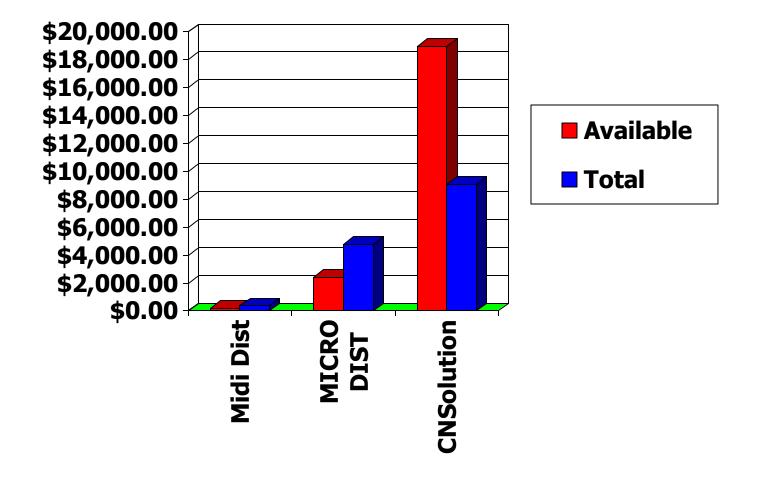






Profit per Shift by Cyanide Species at \$40 per Test Based on Maximum Capacity

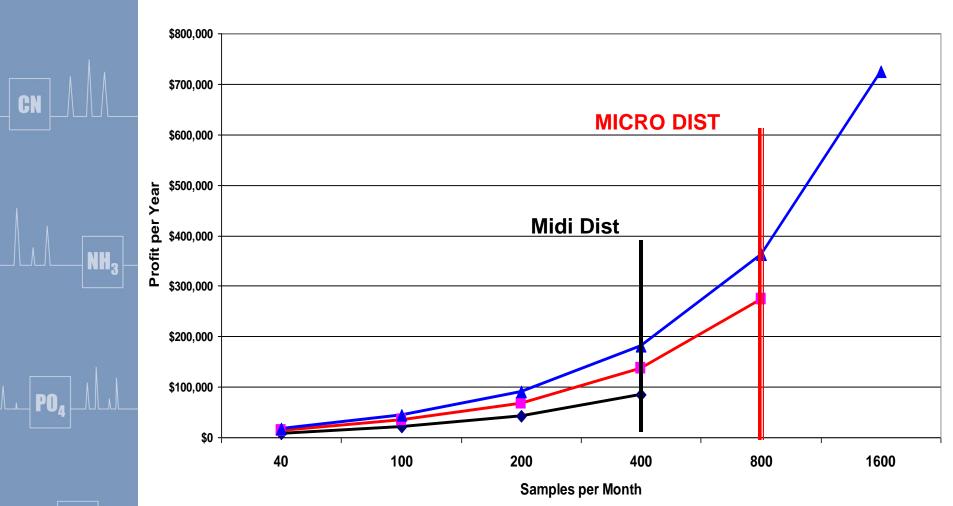








Estimated Profit by Number of Samples Analyzed at Maximum Capacity









Thoughts Regarding "Break Even" Analysis

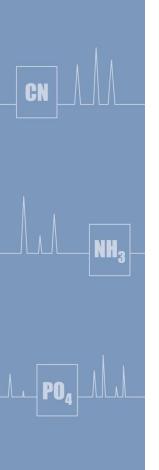
- Manual distillation and manual spectrometer versus CNSolution
 - Manual equipment costs 3 x less
 - CNSolution profit 3 x higher per test
- Break Even = 1000 samples for both!
- That's 20 samples per week regardless

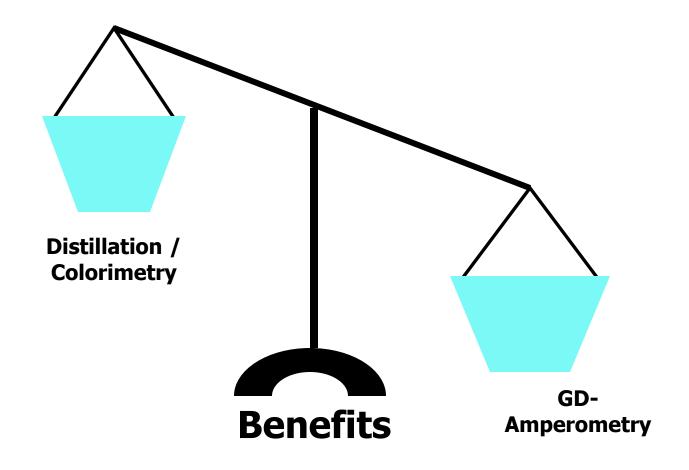






In summary, distillation/colorimetry should be replaced

















Thank You

Questions?

www.oico.com



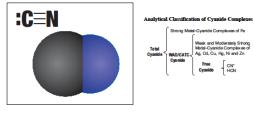




Presented at the 2009 Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Chicago, Illinois
March 8, 2009-March 13, 2009

Introduction

Cyanide analysis methods attempt to measure groups of compounds with similar chemical characteristics and report them as a single value. Various techniques are employed to separate specific types of cyanide complexes from each other and potential matrix interferences to achieve accurate quantitation (Figure 1).



Strong Metal-Cyanide Complexes of Fe

Wask and Moderately Strong Motal-Cyanide Complexes of Ag. Cd, Cu, Hg, Ni and Zn Cyanide

Figure 1. Cyanide refers to a monovalent anion consisting of carbon and nitrogen atoms with triple covalent bonds. Cyanide is very reactive and readily forms metal-cyanide complexes and organic compounds





The regulated community is presented with an array of conflicting definitions of cyanide species, which leads to misunderstandings about what the various techniques and methods actually measure. In fact, the U.S. EPA Solutions to Analytical Chemistry Problems with Clean Water Act Methods "0, or "Pumpkin Guide", states; "Next to oil and grease, cyanide is the pollutant for which the most matrix interferences have been reported to EPA."

This study presents an overview and assessment of the most commonly used cyanide analysis methods including cyanide species measured, analytical techniques employed, potential matrix interferences, and final determinative steps.

Commonly Used Cyanide Analysis Methods

Free Cyanide

Free cyanide refers to the sum of hydrogen cyanide (HCN) and cyanide ion (CN') in a sample (3.3). Free cyanide is bioavailable and approximately a thousand times more toxic to aquatic organisms than it is to humans ⁴⁰. Analytically, free cyanide is referred to as the amount of HCN liberated from solution at pH 6.0.

Weak to Moderately Strong Metal - Cyanide Complexes

Weak to moderately strong metal-cyanide complexes are compounds that dissociate and release bydrogen cyanide gas under middly acidic conditions (M 3 to 6). Cyanide species within this category include: simple cyanides-soluble/dissociable allball metal and alkali earth metal-cyanide complexes (NaCN, ECN, Ca(CN)₂); weak metal-cyanide complexes ($Zn(CN)_2^2$, Cd(CN)₃, N, and moderately strong metal-cyanide complexes ($Zn(CN)_2^2$, Cd(CN)₃, N); and moderately strong metal-cyanide complexes ($Zn(CN)_3^2$). Ag(CN)₃, $Z^{(N)}$, $Z^$

Methods intended to measure weak to moderately strong metal-cyanide complexes also measure simple cyanides. Simple cyanides include free cyanide, alkali metal cyanides, alkali earth metal cyanides, and ammonium cyanide.

Strong Metal-Cyanide Complexes

Publication 32720500

Strong metal-cyanide complexes are compounds that require strongly acidic conditions (pH < 2) to dissociate and release hydrogen cyanide gas $^{(i)}$. Examples of strong metal-cyanide complexes include $Fe(CN)_{g}^{+}$, $Fe(CN)_{g}^{+}$, and $Au(CN)_{2}^{-}$. The strong acidic conditions used to dissociate these resistant metal-cyanide complexes readily dissociates all other cyanide species present in a sample. "Total Cyanide" is the term used in U.S. EPA methods to refer to the sum of all cyanide species that are converted to hydrogen cyanide following reflux distillation of a sample acid in a strong solution.

For a summary of cyanide analysis methods, refer to Table 1.

An Overview and Comparison of Methods for Cyanide Analysis

2







CN _____







Table 1: Summary of CN Analysis Methods

Description Name	Netted	Decaptor	Polestial Interferences	Measurement
Pro Cyalle	ATMODE	Panive Diffusion at pli 6 and executionposition	- Storage - Manifestures	Manual chimination of cyanice with chimenine T and natural and maction with pyridine-bathlank acid. Maximum sharehanch is declared by manual colorinates.
	ASTM D7237	Plew Injection Augment (PLA) later a magnet at a pill of 6-8 - Albahan Chiermatine in	- Simulation - Management	Gas Diffusion-Aroperocally
Andrib Quide (CARC) (Wall)	SM 4500-ON ID	- Alalas Manalin is	- Ramphe light,	Manual chimination of cyanide with
	ASTIM DZENI	destroy all week and dissociable metal-cys- ride completes and any time or slipple cyamide. Two manual destitutions (total-determinal). C. GTC	Incorpte accury on Ay-cyante congisus. Silvaje Distilutes Measured	Gas Diffusion Angueranting Manual chriminion of cynnick with chromation? and subsequed median with psylline hashing a seal. Maximum chromatics is discussed by matual cohomology.
	ASTIM DZENI	Reflect (pt 4.5) minut delitation	Flame of Fe-cyanide complexes. Increptate exempts on Hg cyanide complexes. Storage Outfliding Meanward	Manual oblivitation of cyanide with chromise T and mineralized seation with cyclobe-battleric and action with cyclobe-battleric in distributed by manual colorisative, Manual by Solectine (Sactrolic (SSD), Tilindian.
	ASTIN DATE	Buffered (pl. 6.5) automated Basis desilitation	- Street - Delfidire - Messarened	Astronaid discinnists of cyasile with discussion-T and subsequed matters with pyridine hashina's axid. Astronaid colorinairy
	Coloria El			
	CEA 1677 ASTNI DIGHIS	Preimatowni with ligard #Acharago outperis, room inequation and participated	- Storage - Mexiconnect	Acquiredry
Trial System	SM 4500 CN D	- Cyanide ion à minesal	a Street	Cyanide in the absorber solution is tilested with
	SM ASSOCIALD	Intercognitie completes in IEEN by assessive material estima- distillation in the presence of a stone; publish soil column shift respection chiefes - The IEEN is respit into a think soiline hydroxide absolute solution.	Sirray Distribute Missanneri Missanneri Riccashe Last	Seem datas. Cyanide in the devotive relation is convenient of sparseys distribe by named under which cyanigue distribe by named under with observation T at \$10 ct. After matter, the Cyanigue of the white it is made a sub-linke other or distribute on greatment behalter and of magnet. Maximum other is delevated by customic coloratory.
	ASTIN DZING	 Cyatide ion is referred from yearlie completes as IECS by means of a macro, or leafed dress caused or finds delifialties in the pursued of a stemp miller, and stations and composition Christia. The IECS is respit alons offices societies hydroxide absorber solution. 	- Strape - Definition - Measurement - Exceptive Light	Creation in the shouther solution to thoused with salver streets. Created in the shouther solution in determined created by the obsection illustration Created by the obsection illustration Created by the obsection in the shouther scholaries of an interest with confidence of a first of the obsection in the obsection in the obsection is not obtained in the obsection in the obsection is not obtained in the obsection in the obsection is not obtained in the obsection of the obsection in the obsection obsection is not obsection. Maintenance of the obsection of the obsection is not obsection. Maintenance of the obsection of the obsection obsection is not obsection.
	IPA 135.6	 Opación fon à misqued from cyantile complexam by means of a stacked often traitile means! often destilation in the presence of a strong sollarie, and entirely and composition of brides. The HEN is recept into a distale sociales by physicale abundow solution. 	- Strape - Darfator - Macazonet - Tacashe Lajis	Cyanile in the descrive relation is convented to eposyan of thinks by mile- constant in expension of thinks by mile- constant in the case open of the fall of them, not him color on addition of a gration- habilist call or magest. Maximum color is larker wined by automated colorated.
	Kanada OI, ANTHE DISTRIC IDA 335.3	 Cyutide ion to released from cyutide complexes by came of VV installa- tion and automated flash shallation to the prosence of a strong sublant said mission. The HEN processed in injected ions as said chemistry analyses chem- lately carriedge. 	Strage UV Irestation Dathdrag Management	Cyasile in the abother station to con- verted in cyanoper districts by astronated reaction with Colomator T at pill cd. Alter matters, the cyanoper forms a sel- ther cutter or addition of a pytidase- handmark and request. Maximum color in below mixed by automated colomates.
	ASSNE D73NE	Cyntife ion is released from cyntife complexes by cases of a staled after inside control or co	- Storage - Distriction - Minaconsect	Cyazide in the shorther solution is determined by automated gas diffusion anywerselvy.
	CEA SETBASTIN DESIL-OR	Cyanide ion is released from cyanide complesse by UV strakeline. The IVI prevented diffuse across as resoftness and is measured anyworselficially.	Shouge UV includes Memoranes	Opaside is determined by automated year definition amportunely.

An Overview and Comparison of Methods for Cyanide Analysis

3





CN _____





Potential Method Interferences

Sampling, Preservation, and Storage Interferences

Certain interferences occur during the sampling, preservation, and storage process and apply, to some extent, to all cyanide methods. Chemical preservatives added to samples to preserve the original concentration of cyanide in the sample need to be chosen according to the analytical method that will be used. In general, distillation methods are less forgiving and require extra care in sample pretreatment. Table 2 contains a summary of interferences that result from sample storage and preservation.

Sample Processing Interferences

The sample processing necessary to break metal-cyanide bonds and liberate the cyanide generated from the aqueous sample solution is not interference free. Often, in some sample matrices, the sample processing introduces so much doubt into the measurement that the results cannot be trusted at all. Table 2 contains a summary of interferences that can be introduced during sample processing.

Measurement Interferences

The final measurement technique used to determine the cyanide concentration is also not interference free. Since the final measurement is performed under the assumption that all interferences were previously removed, these interferences often go undetected. This is especially true for automated colorimetric methods. Table 2 contains a summary of interferences that may occur during the final cyanide measurement step.











Table 2: Summary of CN Method Interferences

Residual chlorine, peroxia, or other controlled N/A Read with cyanide in solution rapidly decreasing the cyanide concentration. N/A Read with cyanide in solution rapidly decreasing the cyanide concentration. Staffile N/A Read with cyanide in solution rapidly decreasing the cyanide concentration. Reading is concentration. The reading is concentration. Sample. Reads with cyanide decreasing the cyanide concentration. Sample samples, accordic acid can read with ammonia or other nitrogen sources and increases the cyanide concentration. The some samples, formablely de reads with ammonia or other nitrogen sources and increases the cyanide concentration. The some samples, formablely de reads with ammonia or other nitrogen sources and increases the cyanide concentration. The some samples, formablely de reads with ammonia or other nitrogen sources and increases the cyanide concentration. The some samples accordic acid can read with ammonia or other nitrogen sources and increases the cyanide decreasing its concentration. The samples accordic acid can read with cyanide decreasing its concentration. The samples accordic acid can read with cyanide decreasing its concentration. Staffer Dioxide distill situation absorber solution and reads with cyanide decreasing its concentration. The samples accordinate and reads with cyanide decreasing its concentration. Th			,		
Permission of the continues and the content of the	Analysis Step	Compound		Description of Interference	
Sulfide		peroxide, or other	N/A		
Sampling		Chioramines	N/A	React with sample at pH>10 increasing the cyanide concentration.	
Processing Colloidal sulfury Sulfile N/A Concentration. Reaction is very fast with colloidal sulfur.		Sulfide	N/A	concentration. Reaction is especially rapid if metal sulfides, such as lead	
Suffile N/A Reacts with strong cyanide complexes at pit-1 of decreasing the cyanide concentration. The reaction is almost immediate at pit-1 2.	Progryation, and		N/A		
Assorbic acid NA Reacts with cyanide decreasing the cyanide concentration. Sample holding time when socratic acid is added in less than 4th boars. In some samples, south acid cannot with aumonate or other nitrogen sources and tocrease the cyanide concentration. In some samples, scorbic acid cannot with aumonate or other nitrogen sources and tocrease the cyanide concentration. Formaldehyde N/A Reacts with cyanide decreasing the concentration. In some samples, formalehyde reacts with aumonate or other nitrogen sources and increases the cyanide concentration. Suffride Distillation Distillation Distillation Distillation Distillation and reacts with cyanide decreasing its concentration. Thiosurfact and other ostilized salfuration of the control of the concentration of the concentration. Thiosurfact and other ostilized salfuration of the concentration of the control of the concentration. Passes through diffusion membrane. Reacts with cyanide decreasing its concentration. Distillation and reacts with cyanide decreasing its concentration. Distillation and reacts with cyanide decreasing its concentration. Cyanide Amenable to Chorication. Cyanide Amenable to Chorication. Thiocyanate - Nitration Distillation UV Irradiation UV Irradiation Decomposes to suffur district dist	.non-age	Sulfile	N/A		
Ascothic acid Ascothic acid Ascothic acid is acid is sided is less than 48 hours, in some samples, scorchic acid can raced with ammonia or other nitrogen sources and increase the cyunide concentration. Formaldehyde N/A Reacts with cyunide decoreating its concentration. Suifide Suifide Suifide Suifide Suifide Suifide Obstillation Destillation Distillation Distilla		Light (<350 nm)	N/A	Reacts with strong metal-cyanide complexes releasing free cyanide.	
Pormaldebyde N/A Ashebyde reach with ammonia or other nitrogen sources and increases the cyclaride concentration.		Ascorbic acid	N/A	holding time when ascorbic acid is added is less than 48 hours. In some samples, ascorbic acid can react with ammonia or other nitrogen sources	
Sulfide Sulfide Gas diffusion Distillation Distillation Paness brough diffusion membrane. Reacts with cyariste decreasing its concentration. Distillation in other continue of the cyariste decreasing its concentration. Distillation of the cyariste decreasing its concentration. Distillation Distillation and reacts with cyariste decreasing its concentration. Cyariste Cy		Formaldehyde	N/A	aldehyde reacts with ammonia or other nitrogen sources and increases the	
Suiffe Gas-diffusion Passes through diffusion membrane. Suiffle (or sultra Dioxide) Distillation Passes through diffusion membrane.		Oxidizers	Distillation	Reacts with cyanide decreasing its concentration.	
Suffile (or Sulfur Dioxide) Distillation D		Cuttude	Distillation	Distills into absorber solution and reacts with CN forming thiocyanale.	
(or Sulfire Dictide) Thiosulfaie and chief ordized suffire species (except sulfale) Debilliation Decompose to form native suffire and utilize disconsentation. Debilliation and reacts with cyanide decreasing its concentration. Sulfire Dictide distills into absorber solution and reacts with cyanide decreasing its concentration. Sulfire Dictide distills into absorber solution and reacts with cyanide decreasing its concentration. Sulfire Dictide distills into absorber solution and reacts with cyanide decreasing its concentration. Thiocyanate - Thiocyanate - Nitrale or Nitrite Debilliation Decomposes to sulfire distrible and reacts with cyanide decreasing its concentration. Sulfire distrible sulfire and reacts with cyanide decreasing its concentration. Sulfire distrible sulfire and reacts with cyanide decreasing its concentration. Sulfire distrible sulfire and reacts with cyanide decreasing its concentration. Sulfire distrible sulfire and reacts with cyanide decreasing its concentration. Sulfire distrible sulfire distrible sulfire distribution and generales cyanide. Oncontration Sulfire distribution and generales cyanide. Decompose to form cyanide Titration Decompose to form cyanide with the passes through diffusion membrane Titration Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10 - mg S/L) Gib-Ampenometry Delected as cyanide (at > 10	Sample Processing	Sumge	Gas-diffusion	Passes through diffusion membrane.	
other ostalized saultrus positions and process and process to form nature statiful and statiful conducts. Reset with cyanide decreasing its concentrations. Statiful process destinate into absorber solution and reacts with cyanide decreasing its concentration. Cyantide Amenable to Choinsailon (CATC) Thiocyanale 4 Thiocyanale 5 Thiocyanale 6 Thiocyanale 4 Thiocyanale 6 Thiocyanale 7 Thiocyanale 7 Thiocyanale 7 Thiocyanale 8 Thiocyanale 9 Thiocyanale 1 Thiocyanale 9 Thiocyanale 9 Thiocyanale 9 Thiocyanale 1 Thiocyanale 9 Thiocyanale 1 Thio			Distillation		
Amenable to Chicristics		other oxidized sulfur species	Distillation	decreasing its concentration. Sulfur Dioxide distills into absorber solution	
Decompose to sulfur dioxide and reacts with cyanide decreasing its concentration. Sulfur dioxide dutilits into absorber solution. UV Irradiation		Thiocyanate	Amenable to Chlorination		
Thiocyanale + Nitrale or Nitrite Misc. Organise + Nitrale or Nitrite Misc. Organise + Nitrale or Nitrite Carbonale Carbonale Distillation Decompose to form cyanide Decompose to			Distillation		
Nitrate or Nitrite Destination Decompose to form cyanate			UV Irradiation	Can react at < 280 nm to form cyanide	
Nitrate of Nitrite Destination Decompare to rorm cyanae			Distillation	Decompose to form cyanide	
Gast diffusion Passes through diffusion membrane			Distillation	Decompose to form cyanide	
Tilration Detected as cyanide		Carbonate	Distillation	Excessive foaming and possible violent release of carbon dioxide	
Sulfide Ion Selective Electrode Delected as cyanide Colorimetry Delected as cyanide (at > 10-mg SrL)			Gas diffusion	Passes through diffusion membrane	
Sulfide Colorimetry Detected as cyanide (at > 10-mg SrL.) GID-Amperometry Detected as cyanide (at > 50-mg SrL.) Thiocyanute Colorimetry Detected as cyanide (at > 50-mg SrL.) Patty Acids Titration Mask end point Mask end point Sulfur Dioxide Colorimetry Increase chloromine. T demand resulting in a negative Nas. The increased demand many not be noticed with automated methods.		Sulfide	Titration	Detected as cyanide	
Colorimetry Delected as cyaniske (at > 10-mg SrL) GD-Amperometry Delected as cyaniske (at > 50-mg SrL) Delected as cyaniske (at > 50-mg SrL) Delected as cyaniske Pathy Acids Titration Mask end point Suffur Dioxide Colorimetry Increase chloramine-T demand resulting in a negative bias. The increased demand many not be noticed with automated methods.	Measuronent		Ion Selective Electrode	Detected as cyanide	
Measurement Thiocyanale Colorimetry Detected as cyanide Patty Acids Tilration Mask end point Suffur Dioxide Colorimetry Increase chorumine. T demand resulting in a negative Nas. The increased demand many not be noticed with automated methods.					
Patty Acids Titration Mask end point Increase chloramine-T demand resulting in a negative bias. The increased demand many not be noticed with automated methods.			GD-Amperometry		
Staffur Dioxide Colorimetry Increase chloramine-T demand resulting in a negative bias. The increased demand many not be noticed with automated methods.		Thiocyanate	Colorimetry	Detected as cyanide	
Surur Dioxide Colorimetry demand many not be noticed with automated methods.		Fatty Acids	Titration	•	
Carbonales GD-Amperometry Negative bias at > 1,500-mg CO _g /L				demand many not be noticed with automated methods.	
		Carbonales	GD-Amperometry	Negative bias at > 1,500-mg CO ₂ /L	





