The Hong Kong University of Science and Technology Chemical and Biomolecular Engineering Department

Work Plan: 17038

Title: Gold Recovery from E-waste

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Supervisor: Prof. Tom Luo

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1. General Information

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Name of Supervisors: Tom Luo

Project Title: Gold Recovery from E-waste

Research Area: Environmental

Location: 7109

Proposed Start Date: 19/6/2017

2. Project Description

In Hong Kong, each year there are over 70,000 tons of computers and electronic wastes deposed. Among those electrical waste, they contains quite a large percentage of precious metals such as Gold, and Silver. Few companies a HK are interested in recycling those precious metal. If 1 million cell phone is collected, 24 kg of gold, 250 kg of silver, 9 kg of palladium, and more than 9,000 kg of copper can be recovered. 24kg of gold are worth at least 800 thousand HKD. 1 million cell phone weighs around 150 tons, which is only 0.2% of the local electronic waste. This definitely has a tremendous market potential. In this research, recovering gold is our main target.

Gold has a high electricity conductivity and does not tarnish, this properties have made gold very popular in many industries. Gold is used in electronic industry, soldering semi-conduction, glass production or even spacecraft coating. All this usage are related to advanced technologies, and to be expected to have paramount importance in those area in the future. The usage of gold is getting more and more nowadays, it is a must to find an alternative way to get gold resources besides mining, recovery of gold can a perfect solution to this problem.

3. Equipment List

Equipment

- 1. pH meter
- 2. Analytical balance (±0.001g accuracy)
- 3. Volumetric flasks (1000 ml and 2000 ml)
- 4. Heating plate with magnetic stirring
- 5. Plastic containers
- 6. Syringes
- 7. Borosilicate beakers (250 and 500 ml)
- 8. Desiccator
- 9. Spatula
- 10. Volumetric flask
- 11. Double Distilled water dispenser
- 12. Pipette
- 13. 110mm diameter rapid filter papers, cellulose-based ash-less type
- 14. Electric Hot plate
- 15. Burette 50 ml
- 16. Measuring cylinder
- 17. filter funnel
- 18. Glass microfiber filter media of 1 micron meter particle size
- 19. Suction flask
- 20. Warring Blender
- 21. Refrigerator
- 22. Oil Bath

- 23. Condenser unit
- 24. Vacuum Pump
- 25. Ultrasonic bath
- 26. Carbon Electrodes

4. Experimental Procedures

4.1 Dissolving electronic waste

- 1. Electronic waste is milled by blender.
- 2. 50g of electronic waste will be poured into a 100 ml beaker containing 50 ml hydrochloric acid.
- 3. Take 5 ml of acid solutions for analysis of gold using ICPOES.
- 4. Repeat step 1 and 3 at different reaction temperature (30°C,40°C,50°C), concentration of hydrochloric acid (1M, 2M, 3M, 4M), and reaction time (1hr, 2hrs, 3hrs).
- 5. Repeat step 1 to 4 using 50 ml acid medium containing hydrochloric acid and nitric acid at a ratio of 1:3 at different reaction temperature (30°C,40°C,50°C), ratio of hydrochloric acid and nitric acid (1:1, 1:2, 1:4), and reaction time (1hr, 2hrs, 3hrs).
- 6. The optimal reaction condition for dissolving gold can be found.

4.2 Solvent Extraction

- 1. For using hydrochloric acid as acid medium, 50 ml of electronic waste solution is mixed with 50 ml of toluene in a 250 ml beaker for 1 hour.
- 2. The organic solvent is then extracted and evaporated.
- 3. Repeat step 1 to 2 using ethanol, butanol, acetone, benzene, and hexane as extraction solvent.
- 4. For using both hydrochloric acid and nitric acid as acid medium, 50 ml of electronic waste solution is mixed with 50 ml of ethanol for 1 hour.
- 5. The organic solvent is then extracted and evaporated.
- 6. Repeat step 4 to 5 using acetone, hexane as extraction solvent.

4.3 Chromatography separation

- 1. Prepare a column packed with silica gel.
- 2. Pour 50ml extraction solvent collected from step 4.2.4 into the column.
- 3. Take 5 ml of separated solution for analysis of gold using ICPOES.
- 4. Repeat step 1 to 3 using extraction solvent collected from step 4.2.8.

4.4 Electrolysis

- 1. Prepare a tank for electrolysis
- 2. Add 0.6 g agarose to 40 ml DI water to prepare 1.5% gel.
- 3. Melt the agarose in a microwave oven for 1 minute.
- 4. Let the agarose cool to 55°C and pour the melted agarose in a casting tray.
- 5. Place the gel in the middle of the tank to separate the anode and cathode.
- 6. Pour 50 ml of electronic waste solution collected from 4.1.2 into anode, and pour the equal amount of DI water into cathode.
- 7. Run the electrolysis for 10 minutes.
- 8. Take 5 ml of solution collected from cathode for ICPOES analysis.

- 9. Repeat the step 6 at different reaction time (15 min, 30 min, and 45 min)
- 10. Repeat step 1 to 9 using the different % gel
- 11. Repeat step 1 to 10 using acrylamide gel
- 12. Add 0.2 ml of acrylamide and 0.4 ml of bisacrylamide to 40 ml DI water.
- 13. Pour the solution into a casting tray, and add 5ml of butanol and 5 ml of ammonium persulfate.
- 14. Repeat step 1 to 13 using electronic waste solution collected from 4.1.5.

4.5 Neutralization

- $1. \, \text{Add} \, 50 \, \text{ml}$ of solution from cathode in step $4.4 \, \text{and} \, 50 \, \text{ml}$ of Sodium hydroxide in to a $250 \, \text{ml}$ beaker for different reaction time ($10 \, \text{min}$,
 - 20 min, and 30 min).
- 2. Separate the precipitate by vacuum filtration.
- 3. Take 5 ml of acid solutions for analysis of gold using ICPOES.

4.6 Replacement reaction

- 1. Add 10 g of copper bar into 50 ml of solution from cathode in step 4.4 into a 100 ml beaker and wait for 1 hour.
- 2. Separate the precipitate by vacuum filtration.
- 3. Take 5 ml of acid solutions for analysis of gold using ICPOES.
- 4. Repeat step 1 and 2 using different metal such as Iron, Magnesium, and lead.

4.7 Redox reaction

- 1. Add 10 ml of hydrogen peroxide into 20 ml of solution from cathode in step 4.4 into a 100 ml beaker and wait for 1 hour.
- 2. Separate the precipitate by vacuum filtration.
- 3. Take 5 ml of acid solutions for analysis of gold using ICPOES.

5. Procedure Template

Experimental Experimental Procedure Procedure No. Description 4.1.1 Electronic waste is milled 50g of electronic waste wil ml beaker containing 50 m 4.1.3 Take 5 ml of acid solutions using ICPOES.				
edure No.	Il Procedure	Scale	Location (Fumehood,	
		(Mass/Volume)	benchtop,etc)	Method (New or Existing)
	Electronic waste is milled by blender.	Not available	benchtop	Existing
	50g of electronic waste will be poured into a 100 ml beaker containing 50 ml hydrochloric acid.	50ml HCl	Fumehood	Existing
	Take 5 ml of acid solutions for analysis of gold using ICPOES.	Not available	7101	Existing
	Repeat step 1 and 3 at different reaction	150 ml HC1	[]	
temperature (3	temperature (30°C,40°C,50°C), concentration of		r unienood	Existing
hydrochloric	hydrochloric acid (1M, 2M, 3M, 4M), and reaction			
time (1hr, 2hrs, 3hrs).	s, 3hrs).			
4.1.5 Repeat step 1	Repeat step 1 to 4 using 50 ml acid medium	50ml HNO ₂	Fumehood	Existino
containing hyd	containing hydrochloric acid and nitric acid at a	ז		9
ratio of 1:3 at	ratio of 1:3 at different reaction temperature			
(30°C,40°C,50	(30°C,40°C,50°C), ratio of hydrochloric acid and			
nitric acid (1:1	nitric acid (1:1, 1:2, 1:4), and reaction time (1hr,			
2hrs, 3hrs).	,			
4.1.6 The optimal re	The optimal reaction condition for dissolving gold	Not available	benchtop	Existing
can be found.)

4.2 Solvent Extraction	action			
Kynorimontel	Renerimental Denominantal December		Location	
Procedure No. Description	Description	Scale (Mass/Volume)	(Fumehood,	Mothed (More on Periodical)
	For using hydrochloric acid as acid medium, 50 ml		(and amount	Existing
	of electronic waste solution is mixed with 50 ml of	_		9 mary
4.2.1	toluene in a 250 ml beaker for 1 hour.	50 ml toluene	Fumehood	
	The organic solvent is then extracted and			Fvicting
4.2.2	evaporated.	Not available	Fumehood	LAISUIR
4.2.3		50 ml ethanol, butanol	Firmehood	Viction
	Repeat step 1 to 2 using ethanol, butanol, acetone,	acetone, benzene, and		Farshing
	benzene, and hexane as extraction solvent.	hexane		
4.2.4	For using both hydrochloric acid and nitric acid as	50 ml ethanol	Fumehood	Evicting
			T WILLIAM T	

	Existing	Existing
	Fumehood	Fumehood
	Not amilable	50 ml acetone, and hexane
acid medium, 50 ml of electronic waste solution is mixed with 50 ml of ethanol for 1 hour.	The organic solvent is then extracted and evanorated	Repeat step 4 to 5 using acetone, hexane as extraction solvent.
	4.2.5	4.2.6

4.3 Chromatography separation	aphy separation			
Experimental Experiment	Experimental Experimental Procedure	Scale	Location (Fumehood,	,
T TOPPORT C TAO:	Description	(Iviass/ volume)	benchtop,etc)	Method (New or Existing)
4.3.1	Prepare a column packed with silica gel.	100g silica gel	benchtop	Existing
4.3.2	Pour 50ml extraction solvent collected from step	; ;	benchtop	Existing
	4.2.4 into the column.	Not available)
4.3.3	Take 5 ml of separated solution for analysis of gold		7101	Existing
	using ICPOES.	Not available		0
4.3.4	Repeat step 1 to 3 using extraction solvent		benchton	Existing
	collected from step 4.2.6.	100g silica gel	4	Que
		כ	•	

4.4 Electrolysis		-		
			Location	
Experimental	Experimental Procedure	Scale	(Fumehood.	
Procedure No.	Description	(Mass/Volume)	benchton etc)	Mathod (Now or Eviction)
4.4.1	Prepare a tank for electrolysis	Not available	Benchton	Existing
4.4.2	Add 0.6 g agarose to 40 ml DI water to prepare		Benchton	Existing
	1.5% gel.	0.6 g agarose	-	0
4.4.3	Melt the agarose in a microwave oven for 1 minute.		Benchtop	Existing
4.4.4	Let the agarose cool to 55°C and pour the melted		Benchtop	Existing
	agarose in a casting tray.	Not available	4	quincin
4.4.5	Place the gel in the middle of the tank to separate		henchton	Fyicting
	the anode and cathode.	Not available	domana	FAISTIRE
4.4.6	Pour 50 ml of electronic waste solution collected		henchton	Fvieting
	from 4.1.2 into anode, and pour the equal amount		Journal	Simple
	of DI water into cathode.	Not available		
4.4.7	Run the electrolysis for 10 minutes.	Not available	Firmphood	Lvioting
4.4.8	Take 5 ml of solution collected from cathode for	Not available	7101	LAISUILB
		ALOS MAGINOIS	101	DXIXI

	ICPOES analysis.			
4.4.9	Repeat the step 6 at different reaction time (15 min		Distance of the contract	
			rumenood	Existing
	30 min, and 45 min)	3 g agarose		0
4.4.10	Repeat step 1 to 9 using the different % gel	10 o agarose	Bonohton Gunologa	
1 1 1 1 1		acomen a or	Delication, Inflictiona	Existing
4.4.11	Repeat step 1 to 10 using acrylamide gel	Not available	Benchtop, fumehood	Existino
4.4.12	Add 0.2 ml of acrylamide and 0.4 ml of	0.2 ml acrylamide	Firmehood	Duinting
	bisacrylamide to 40 ml DI water.	0.4 ml hisacrylamide		FAISTING
1112		ביו יווו סופתר אומווותר		
C1.+.+		5ml butanol		Existing
_	Pour the solution into a casting tray, and add 5ml of	5ml of 5 ml ammonium		
		persulfate	Filmehood	
1111		Annua -	1 miliculoud	
4.4.14		13 g agarose		Existing
_		0.2 ml acrylamide)
		0.4 ml bisacrylamide		
		5ml butanol		
	Repeat step 1 to 13 using electronic waste solution	5 ml ammonium		
	collected from 4.1.5.	persulfate	Fumehood	
			TO TO THE T	

4.5 Neutralization	uc			
Vernominator	T		Location	
D. J. J. M.	Procedure of the perimental Procedure	Scale	(Fumehood,	
Frocedure No. Description	Description	(Mass/Volume)	benchtop,etc)	Method (New or Existing)
	Add 50 ml of solution from cathode in step 4.4 and		Fumehood	Evicting
	50 ml of Sodium hydroxide in to a 250 ml beaker			Sime
	for different reaction time (10 min, 20 min, and 30			
4.5.1		150 ml Sodium hydroxide		
4.5.2	Separate the precipitate by vacuum filtration.	Not available	Firmehood	Tvieting
453	Take 5 ml of soid colutions for such size 2		T MILIONAL TO THE TANK THE TAN	CAISUING
; ;	Tank July of acta solutions for analysis of gold		Fumehood	Existing
	using ICPOES.	Not available		0
			_	_

4.6 Replacement reaction	t reaction			
Experimental	Experimental Experimental Procedure	Scale	CEumobood	
Procedure No. Description	Description	(Mass/Volume)	henchton etc)	Mother Officers
	Add 10 g of conner har into 50 ml of 11.4:		Scarinop, city	intellion (New or Existing)
	Trad to g of copper bar little 30 fill of solution from		benchtop	Existing
	cathode in step 4.4 into a 100 ml beaker and wait for		4	Simon
4.6.1		10 g conner		
160		to & copper		
4.0.7	Separate the precipitate by vacuum filtration.	Not available	henchton	17.00.00
163	Toloo &			CAISUILB
0.0.1	Take Juli of acid solutions for analysis of gold	Not available	7101	Fvicting
			101	LAISTIILE

	using ICPOES.			
4.6.4	Repeat step 1 and 2 using different metal such as	10 g Iron, Magnesium,	benchtop	Existing
	Iron, Magnesium, and lead.	and lead)
4.7 Redox reaction	no			
			Location	
Experimental	Experimental Experimental Procedure	Scale	(Firmehood)	
Procedure No.	Description	(Mass/Volume)	benchton.etc)	Method (New or Evicting)
	Add 10 ml of hydrogen peroxide into 20 ml of		Filmehood	Frieding (1909 of Easting)
	solution from cathode in step 4.4 into a 100 ml			Guranig
4.7.1		10 ml hydrogen peroxide		
4.7.2	Separate the precipitate by vacuum filtration.	Not available	Fumehood	Fyicting
	Take 5 ml of acid solutions for analysis of gold		7101	Lvicting
4.7.3	using ICPOES.	Not available		Similar

6. HAZOP Analysis
HAZOP Template

DACO	nazor lempiate						
Hazarc	I and Operability Ana	Hazard and Operability Analysis (4.1 Dissolving electronic waste)	tronic waste)				
NO	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	MINIMISE BISK BV	DECEMBER 1 P. 1017
4.1.1	Blade from blender	Physical injuries of	M	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	T	MINIMISE NISK BI	KESIDUAL KISK
		fingers	Iaĭ	1	<u>۔</u>	Get training for proper	7
4.1.2	Contact with	Skin eve and	N	17	11	operation of equipment	
	hydrochloric acid	ropoint town insitution	TAT	11	Ľ.	Prepare stock solution and	Σ
	וואשוסכוווסוווכ מכות	respiratory irritation				carry out reaction in fume	
						hood. Always wear lab	
						coat, gloves and safety	
4.1.3	Not available					goggles	
414	Hot heat plate	Drinned alrin	7.4				
	LIOUTING PIGUE		Ξ	W	Σ	Wear heat protective	T
						gloves, lab coat and safety	
						goggles. Put up warning	
			-			sign Collect samples only	
						when they are cooled to	
						room temperature	
4.1.5	Contact with	Skin, eye and	M	Н	Н	Prepare stock solution and	×
	hydrochloric acid	respiratory irritation				Correy Out resoction in Guns	T.1
	and nitric acid					hood Always wear lab	
_						coot along and affect.	
						coat, gloves and salety	
4.1.6	Not available					S S S S S S S S S S S S S S S S S S S	
4.1.7	Contact with sulfuric	Skin, eve and	×	П	П		
	acid	rechiratory imitation	141	11	Ľ	Frepare stock solution and	Σ
		respiratory infiliation				carry out reaction in fume	
						hood. Always wear lab	
						coat, gloves and safety	
						goggles	
4.1.8	Contact with	Skin, eye and	\mathbb{Z}	Н	H	Prepare stock solution and	M
	nyarochioric acid	respiratory irritation	_			carry out reaction in fume	
						hood. Always wear lab	
				_		coat, gloves and safety	
						gogoles	
FINAL	ASSESSMENT: User	User can protect themselves	with proper	protect themselves with proper training and take	OVERALI RICK	BISK.	
precaution			Tada d			- Man	M
Remark:		Severity-Low:1 (Minor injuries, first aid): Medium:2 (Hosnitalization medical lawa): Uich:2 (Section 2)	: Medium:2 (Tosnitalization med	(ayaa)		

:: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZO	HAZOP Template				•		
Hazar	I and Operability Ana	Hazard and Operability Analysis (4.2 Solvent Extraction)	ou)				-
NO	HAZARD	HAZARD EFFECT	VERITY	PROBABILITY	RISK	MINIMISE PICK BV	DECIDITAT DICE
4.2.1		Skin, eye and		H	H	n and	RESIDUAL KISK
	hydrochloric acid						1
	and toluene	Toxic to health if				hood. Always wear lab coat,	
		swantowed of offentied in.				gloves and safety goggles	
4.2.2	Not available						
4.2.3	Contact with ethanol,	Skin, eye and	H	Н	Ή	-	
	butanol, acetone,	respiratory irritation.	ı	1	11	carry out reaction in fund	
	benzene, or hexane	Toxic to health if				hood. Always wear lab coat	
		swallowed or breathed				gloves and safety goggles	_
		ın.					
4.2.4			Н	H	Н	Prepare stock solution and I	
	hydrochloric acid					carry out reaction in fume	1
	and nitric acid	Toxic to health if				hood. Always wear lab coat.	-
		swallowed or breathed				gloves and safety goggles	_
		in.					
4.2.5	Not available						
4.2.6	Contact with	Skin, eye and	Н	Н	H	Prepare stock solution and	
		respiratory irritation.					
	nitric acid, acetone	Toxic to health if				hood Always wear lab coat	
	and hexane	swallowed or breathed				ploves and safety googles	
		in.				Socied Section of the	
FINAL	ASSESSMENT: User c	FINAL ASSESSMENT: User can protect themselves with proper training and take precaution	1 proper trainii	ng and take precautio	n	OVERALL RISK:	

Remark: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZOP Template	[emplate						
Hazard a	nd Operability Anal	Hazard and Operability Analysis (4.3 Chromatography separation)	y separation)				
NO	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	SEVERITY PROBABILITY RISK MINIMISE DISK DV	DEGINITAL PROFE
121	D1.		1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	ATOM	INTENTINED INDU DI	RESIDUAL KISK
1.7.1	break of glass scratch on skin	scratch on skin		1	T	he careful with placing and	-
	apparatus					handling the entire than	1
	1 1 1 1					manual mose instruments	
4.5.2	Not available						
4.3.3	Not available						
1							
4.5.4	Not available						
TATATE	THE WINDS CONTON]				
FINALA	SSESSMEN I: User c	FINAL ASSESSIMENT: User can protect themselves with proper training and take precaution	th proper traini	ng and take precaution	=	OVERALI RISK.	

NAL ASSESSMEN I: User can protect themselves with proper training and take precaution | OVERALL RISK: | L
Remark: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZOI	HAZOP Template						
Hazard	and Operability	Hazard and Operability Analysis (4.4 Electrolysis)	sis)				
NO No	HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	MINIMISE RISK BY	PECIDITAL DICK
4.4.1	Not available						ACSIDOAL KISK
4.4.2	Contact with	Skin, eve and	Σ	Ħ	П	Dramary atout colution	
	agarose	respiratory irrita		:	-	repare soots solution and carry our reaction in fume hood. Always wear	- W
		+				lab coat, gloves and safety goggles	
4.4.3	Hot solution	Burned skin	$\mathbf{Z}_{\mathbf{z}}$	M	Σ	Wear heat protective gloves, lab coat	T
	from microwave	-				and safety goggles. Put up	
						Collect samp	
						when they are cooled to room	
7 7 7	Mot erreitable					temperature	
+ + +	ivot available						
4.4.5	Not available						3 3 5 5 5
4.4.6	Not available						
4.4.7	Electronic	Electric shock	>		1	Aur.	-
	device			1	ו	oloves	
4.4.8	Not available					Broves	
4.4.9	Not available						
4.4.10	Contact with	Skin eve and	×			-	i i
		forming of	TAT		Ę.		Σ
	agai Ooc	respiratory irritation				reaction in fume hood. Always wear	
4.4.11	Not available				1	ian coat, gioves and salety goggles	
4.4.12	Contact with	Skin, eye and	M	H	Н	Prepare stock solution and carry out	M
	acrylamide or	respirato		-			ΙΔΥ
	bisacrylamide					lab coat, ploves and safety opogles	
4.4.13	Contact with	Skin, eye and	M	Н	Н	+	N
	butanol or	respiratory irritation			1		IAI
	ammonium					lab coat, gloves and safety googles	
	persulfate.					10 10 10 10 10 10 10 10 10 10 10 10 10 1	_
4.4.14	Not available						
FINALA	SSESSMENT: Us	FINAL ASSESSMENT: User can protect themselves with proper training and take precontion	es with proper	training and take no	1	OVED ATT BIOV.	1 P
Rema	rk: Severity-Low	1 Minor injuries fire	+ aid). Madim	and the and take pi	iccaution		
	TATE TATE	THE STATE OF THE S	A ALL MENIE		The Track		F-4-11-1-11-11-11-11-11-11-11-11-11-11-11

: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZOF	HAZOP Template							
Hazard	Hazard and Operability Analysis (4.5 Neutralization)	Analysis (4.5	5 Neutralizati	ou)				
NO	HAZARD	HAZARI) EFFECT	HAZARD EFFECT SEVERITY	PROBABILITY	RISK	RISK MINIMISE RISK BV	DECIDITAT DICE
	Contact with		eye and	M	H	H	tuo puo	MESILUCAL MISA
451	Sodium	respirator	respiratory irritation					IM
	hydroxide					•	lah coat aloves and safety goods.	_
4.5.2	Not available						tas cour, groves and saidly goggles	
4.5.3	Not available							
4.5.4	Contact with	Skin,	eye and	X	H	Ξ	Prepare ctock colution and commercial	
	Sodium	respirator	respiratory irritation			;	restion in firms bood Alman man	<u>. </u>
	hydroxide	•					lab coat gloves and cafety googles	
4.5.5	Contact with	Skin,	eye and	M	H	H	+	
	agarose	respirator	respiratory irritation		•			
							lab coat, gloves and safety goggles	
FINAL	ASSESSMENT: U	ser can prote	ct themselves	s with proper tr	FINAL ASSESSMENT: User can protect themselves with proper training and take precaution	aution	OVERALL RISK:	
Domo	Domond: Committee I Office			;		İ		

Remark: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZ0	HAZOP Template						
Hazar	and Operability,	Hazard and Operability Analysis (4.6 Replacement reaction)	nent reaction)				
0N	HAZARD	HAZARD EFFECT SEVERITY	SEVERITY	PROBABILITY	RISK	RISK MINIMISE RISK BV	DECIDITAL DICK
4.6.1	4.6.1 Not available					I d word down with	MESIDOAL NISK
160	Mot armilalia						
4.0.4	4.0.2 INOLAVAIIADIE						
4.6.3	4.6.3 Not available						
4.6.4	4.6.4 Not available						
FINAL	ASSESSMENT: U	ser can protect themse	lves with prope	FINAL ASSESSMENT: User can protect themselves with proper training and take precaution		OVER ALL RISK:	

INAL ASSESSMENT: User can protect themselves with proper training and take precaution | UVERALL KISK: | L
Remark: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

HAZ	HAZOP Template		ŀ		İ		
Hazaı	Hazard and Operability Analysis (4.7 Solvent Extraction)	lysis (4.7 Solvent Extrac	ction)				
NO	NO HAZARD	HAZARD EFFECT	SEVERITY	PROBABILITY	RISK	HAZARD EFFECT SEVERITY PROBABILITY RISK MINIMISE RISK BY	RESIDIAL RISK
4.7.1	4.7.1 Contact with hydrogen Skin, eye and M	Skin, eye and	×	H	Н	Prepare stock solution and carry M	W
	peroxide	respiratory irritation				out reaction in fume hood. Always	
						wear lab coat, gloves and safety	
						goggles	
4.7.2	4.7.2 Not available						
4.7.3	4.7.3 Not available						
FINA	FINAL ASSESSMENT. Hear can protect themselves with proper training and take proposition OVED ALL DICK.	an protect themselves	ith proper train	ing and take magain		OVED ATT BIGIT.	1
4 77 77 ~	The state of the s	an protect dictions of	vidi propor dali	IIIIB allu lanc picca	מנוסוו	OVERALL RISK:	ĭ.

Remark: Severity-Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability-

7. Operating condition

Temperature: 20°C- 70°C

Pressure: atmospheric

Flow rates: Batch operation, N/A

8. Services List

Electric power: 220V, 15A

Water: distilled water, tap water, DDI water

Gas: Compressed air Fume hood in 7109

9. Chemical List

No.	Chemical	Purity	Quantity	per
			Experiment	
(1)	Hydrochloric acid	37%	250mL	
(2)	Nitric acid	65%	250mL	
(3)	Hexane	95%	250mL	
(4)	Ethanol	95%	250mL	
(5)	Toluene	95%	250mL	
(6)	Agarose	100%	50g	
(7)	Silica gel	100%	50g	
(8)	Hydrogen peroxide	30%	250mL	<u> </u>
(9)	Sodium hydroxide	30%	250mL	
(10)	Copper	90%	10g	<u> </u>
(11)	• • • Acrylamide	90%	100mL	<u> </u>
(12)	Bisacrylamide	90%	100mL	
(13)	Ammonium persulfate	90%	100mL	
(14)	Iron	90%	10g	
(15)	Magnesium	90%	10g	

(16)	Lead	90%	10g
(17)	Acetone	95%	100Ml
(18)	Benzene	95%	100mL

10. Biological Agent List Nil

11. Summary of Relevant Hazard and Incompatibilities

Material	Summary of Hazards	Incompatibilities
Hydrochloric acid	Corrosive to metals. Severe skin and eye burns. Respiratory Irritation.	Bases, Amines, Alkali metals, Metals, permanganates, e.g. potassium permanganate, Fluorine, metal acetylides, hexalithium disilicide
Nitric acid	May intensify fire; oxidizer. May be corrosive to metals. Causes severe skin burns and eye damage.	Alkali metals, Acetic anhydride, Organic materials, Alcohols, Acetonitrile, Acrylonitrile
Hexane	Highly flammable, Harmful, Irritant, Dangerous to environment	Strong oxidizing agent
Ethanol	Highly flammable liquid and vapor. May form explosive mixtures with air	Alkalis and oxidizing agents
Toluene	Flammable, Severe respiratory Irritation.	Oxidizing agent
Agarose	Slightly hazardous in case of skin contact or eye contact, will lead to irritation.	Nil
Silica gel	Slightly hazardous in case of skin contact or eye contact, will lead to irritation.	Nil
Hydrogen peroxide	Severe skin irritation and eye inflammation. Respiratory Irritation.	Oxidizing agents, reducing agents, combustible materials, organic materials, metals, acids, alkalis.

Sodium hydroxide	Severe skin and eye burn. Severe respiratory Irritation.	Oxidizing agents, reducing agents, metals, acids, alkalis, moisture.	
Copper	Slightly skin and eye irritation.	Nil	
Acrylamide	Severe skin and eye burns. Respiratory Irritation.	Oxidizing agent, acids, alkalis and moisture.	
Bis-acrylamide	Skin and eye burns. Respiratory Irritation. Prolonged or repeated exposure affects the nervous system.	Strong oxidizing agent, strong reducing agent, strong acid and strong alkali	
Ammonium persulfate	Severe skin burn, and inhalation irritation.	Reducing agents, combustible materials, organic materials, metals.	
Iron	Skin and eye irritation.	Oxidizing agent and acid	
Magnesium	Skin and eye Irritation.	Oxidizing agent, acid and moisture	
Lead	Skin and eye Irritation.	Oxidizing agent.	
Acetone	Severe skin burn, inhalation and skin irritation.	Oxidizing agent, reducing agent, acid and alkali	
Benzene	Skin, eye and inhalation irritation	Oxidizing agent and acid	

12. Waste List

- 1. Large amount of sodium hydroxide, hydrochloric acid and nitric acid are neutralized to pH7 before disposal into sink. Small amount will be disposed directly into alkaline and inorganic acid waste barrel.
- 2. Chlorine containing solvent, such as dichloromethane will be disposed into hydrogenated organic solvent waste barrel.
- 3. Other organic solvent will be disposed into non-hydrogenated organic solvent waste barrel.
- 4. Metal waste will be disposed into metal waste container.

13. Assessment of Significant Risks

In this experiment, highly flammable solvent are used, keep those solvents away from heat source, flame source and sparks.

Highly toxic organic solvents are used, always handle the chemicals in fume-hood to prevent breathing in toxic vapors.

Sodium hydroxide, hydrochloric acid and nitric acid are involved, which is highly corrosive can lead to severe

skin burn. Wear personal protective equipment all the times, and carry the experiment in fume-hood to avoid breathing in acid fume.

14. Safety Precaution

Safety Training Required

Safety training courses, included Chemical Safety and Hazardous Waste Management training organized by the HSEO should be attended.

Equipment Training Required

Training with technician to use the characterization instruments in lab 7101 and processing equipment in 7109 should be arranged.

Personal Protective Equipment

Laboratory coat, safety glasses, gloves, heat gloves (while handling hot samples) and goggles are worn throughout experiments

Fume-hood will be used when handling hazardous and flammable chemicals listed in the Chemical and Materials section.

In the event of emergency (e.g. chemical spillage) workers' actions will follow the standard procedures suggested by University's Chemical Safety training as well as Emergency Procedures.

Safety precautions of flammable liquids

- 1. Keep the flammable chemicals away from heat and ignition sources.
- 2. Do not leave the containers opened as vapors can flow along surfaces and travel a considerable distance to a source of ignition and flash back.

Warning sign required

- 1. All the chemicals will be stored based on the hazard categories with clear labeling.
- 2. The composition of the chemicals, date of receipt, use and expiration must be noted on label.
- 3. Chemical inventory will be minimized to reduce the overall risks.
- 4. Labels of HIGH VOLTAGE and HIGH CURRENT must be noted and be seen clearly.
- 5. Put up warning signs with the contact number of researcher when reactions are being carried out.

Emergency Procedures

- 1. Ventilated area and wash spill site after material pickup is complete. Evacuate area.
- 2. If inhaled the toxic fumes, remove to fresh air. If breathing is difficult, give oxygen.
- 3. In case of skin contact, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician.
- 4. If the situation is out of control, evaluate from the scene immediately. Alert others people to evaluate from the scene immediately. Inform SEPO and security unit promptly about the incident.

15. Action in case of Abnormal or emergency situation

In the event of emergency workers' actions will follow the standard procedures suggested by University's Chemical Safety training as well as Emergency Procedures. All abnormality during experiment shall be reported to laboratory technical staff immediately.

In case of Chemical Spill

Hazardous Chemical Spill in Research Laboratory

- Alert co-workers
- Carry out emergency shut-down: shut down the analysis run via software (in low pressure analysis), or press red "Emergency Stop" button immediately for 2-3 seconds (in high pressure analysis).
- Report to laboratory technical staff immediately;
- If safe to do so, confine the spill with appropriate materials. Turn off remotely all heat/ignition sources if flammable vapor is involved.
- Ask for assistance if necessary. Press the Emergency Ventilation bottom (do not activate this bottom in case of fire).
- Inform the Security Control Centre by dialing 8999 from a safe location.
- Evacuate everyone in the affected area. Leave contaminated clothing and close the door.
- Activate local warning system to prevent others from entering the room.
- If possible, maintain a safe distance from the scene, keep the entrance or access routes in sight and help to prevent entry to the affected room.
- If conditions allow, remain to assist the emergency response team.

In case of Fire

When you hear fire alarm:

- Remain calm and check if there is any sign of fire in the vicinity.
- If you see fire or smoke, or hear the announcement asking you to evacuate, follow the evacuation procedures.
- If there is no sign of a fire, stay alert and pay attention to announcement until the fire alarm is silenced.
- Evacuate of the alarm has sounded for more than two minutes

If you discover a fire:

- Activate the fire alarm by pressing the breakglass fire alarm button located at the corridor.
- Report to Security Control Centre by dialing 8999.
- Alert other people. If SAFE to do so, try to put out the fire by firefighting equipment.
- DO NOT take any personal risk. If the fire gets beyond your control, evacuate immediately by following the procedures below.

• Close the door of the room on fire.

When someone is injured or ill:

- Call Security Control Centre (SCC) by dialing 8999.
- Call for Community Emergency Service directly by dialing (9)999 if the situation is urgent or serious and inform SCC subsequently.
- DO NOT conduct rescue operation, unless you know for sure how to perform a proper rescue and you know the situation is safe? Careless rescue operation may endanger the rescuers when, for example, the victim is inside a room filled with toxic gas, or is still in contact with live electricity.
- DO NOT move an injured person, especially when there are signs of spinal injury or bone fracture, unless it is absolutely necessary to do so for safety reason.
- Keep the injured or ill person comfortable, warm, and lying down.
- Give First aid treatment if necessary.
 - 1. Acid and alkali burns--flush with running water; use emergency shower if necessary. Do not attempt to neutralize.
 - 2. Heat or cold burns--flush with cold water.
 - 3. Chemical in eyes--flush eyes with emergency eyewash.
 - 4. Major bleeding--apply direct pressure to the wound using a clean cloth.
 - 5. Toxic gas inhalation-expose to fresh air.
 - 6. Hydrofluoric acid exposure--use antidote immediately
 - 7. Cyanide exposure--use antidote immediately