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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**1. General Information**

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Project Title: Gold Recovery from E-waste
Research Area: Environmental
Location: 7109
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## 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. Add 50 ml of solution from cathode in step 4.4 and 50 ml of Sodium hydroxide in to a 250 ml beaker for different reaction time (10 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**

| 4.1 Dissolving electronic waste | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.1.1 | Electronic waste is milled by blender. | Not available | benchtop | Existing |
| 4.1.2 | 50g of electronic waste will be poured into a 100 ml beaker containing 50 ml hydrochloric acid. | 50ml HCl | Fumehood | Existing |
| 4.1.3 | Take 5 ml of acid solutions for analysis of gold using ICPOES. | Not available | **7101** | Existing |
| 4.1.4 | 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). | 150 ml HCl | Fumehood | Existing |
| 4.1.5 | 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). | 50ml $HNO_3$ | Fumehood | Existing |
| 4.1.6 | The optimal reaction condition for dissolving gold can be found. | Not available | benchtop | Existing |

| 4.2 Solvent Extraction | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.2.1 | 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. | 50 ml toluene | Fumehood | Existing |
| 4.2.2 | The organic solvent is then extracted and evaporated. | Not available | Fumehood | Existing |
| 4.2.3 | Repeat step 1 **to 2** using ethanol, butanol, acetone, benzene, and hexane as extraction solvent. | 50 ml ethanol, butanol, acetone, benzene, and hexane | Fumehood | Existing |
| 4.2.4 | For using both hydrochloric acid and nitric acid as | 50 ml ethanol | Fumehood | Existing |

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

| 4.3 Chromatography separation | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, 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 4.2.4 into the column. | Not available | benchtop | Existing |
| 4.3.3 | Take 5 ml of separated solution for analysis of gold using ICPOES. | Not available | 7101 | Existing |
| 4.3.4 | Repeat step 1 to 3 using extraction solvent collected from step 4.2.6. | 100g silica gel | benchtop | Existing |

| 4.4 Electrolysis | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.4.1 | Prepare a tank for electrolysis | Not available | Benchtop | Existing |
| 4.4.2 | Add 0.6 g agarose to 40 ml DI water to prepare 1.5% gel. | 0.6 g agarose | Benchtop | Existing |
| 4.4.3 | Melt the agarose in a microwave oven for 1 minute. | Not available | Benchtop | Existing |
| 4.4.4 | Let the agarose cool to 55°C and pour the melted agarose in a casting tray. | Not available | Benchtop | Existing |
| 4.4.5 | Place the gel in the middle of the tank to separate the anode and cathode. | Not available | benchtop | Existing |
| 4.4.6 | Pour 50 ml of electronic waste solution collected from 4.1.2 into anode, and pour the equal amount of DI water into cathode. | Not available | benchtop | Existing |
| 4.4.7 | Run the electrolysis for 10 minutes. | Not available | Fumehood | Existing |
| 4.4.8 | Take 5 ml of solution collected from cathode for | Not available | 7101 | Existing |

| | | | | |
|---|---|---|---|---|
| | ICPOES analysis. | | | |
| 4.4.9 | Repeat the step 6 at different reaction time (15 min, 30 min, and 45 min) | 3 g agarose | Fumehood | Existing |
| 4.4.10 | Repeat step 1 to 9 using the different % gel | 10 g agarose | Benchtop, fumehood | Existing |
| 4.4.11 | Repeat step 1 to 10 using acrylamide gel | Not available | Benchtop, fumehood | Existing |
| 4.4.12 | Add 0.2 ml of acrylamide and 0.4 ml of bisacrylamide to 40 ml DI water. | 0.2 ml acrylamide<br>0.4 ml bisacrylamide | Fumehood | Existing |
| 4.4.13 | Pour the solution into a casting tray, and add 5ml of butanol and 5 ml of ammonium persulfate. | 5ml butanol<br>5 ml ammonium persulfate | Fumehood | Existing |
| 4.4.14 | Repeat step 1 to 13 using electronic waste solution collected from 4.1.5. | 13 g agarose<br>0.2 ml acrylamide<br>0.4 ml bisacrylamide<br>5ml butanol<br>5 ml ammonium persulfate | Fumehood | Existing |

| 4.5 Neutralization | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.5.1 | Add 50 ml of solution from cathode in step 4.4 and 50 ml of Sodium hydroxide in to a 250 ml beaker for different reaction time (10 min, 20 min, and 30 min). | 150 ml Sodium hydroxide | Fumehood | Existing |
| 4.5.2 | Separate the precipitate by vacuum filtration. | Not available | Fumehood | Existing |
| 4.5.3 | Take 5 ml of acid solutions for analysis of gold using ICPOES. | Not available | Fumehood | Existing |

| 4.6 Replacement reaction | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.6.1 | 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. | 10 g copper | benchtop | Existing |
| 4.6.2 | Separate the precipitate by vacuum filtration. | Not available | benchtop | Existing |
| 4.6.3 | Take 5 ml of acid solutions for analysis of gold | Not available | 7101 | Existing |

| | | | | |
|---|---|---|---|---|
| | using ICPOES. | | | |
| 4.6.4 | Repeat step 1 and 2 using different metal such as Iron, Magnesium, and lead. | 10 g Iron, Magnesium, and lead | benchtop | Existing |

| 4.7 Redox reaction | | | | |
|---|---|---|---|---|
| **Experimental Procedure No.** | **Experimental Procedure Description** | **Scale (Mass/Volume)** | **Location (Fumehood, benchtop,etc)** | **Method (New or Existing)** |
| 4.7.1 | 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. | 10 ml hydrogen peroxide | Fumehood | Existing |
| 4.7.2 | Separate the precipitate by vacuum filtration. | Not available | Fumehood | Existing |
| 4.7.3 | Take 5 ml of acid solutions for analysis of gold using ICPOES. | Not available | 7101 | Existing |

**6. HAZOP Analysis**

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.1** Dissolving electronic waste) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.1.1 | Blade from blender | Physical injuries of fingers | M | L | L | Get training for proper operation of equipment | L |
| 4.1.2 | Contact with hydrochloric acid | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.1.3 | Not available | | | | | | |
| 4.1.4 | Hot heat plate | Burned skin | M | M | M | Wear heat protective gloves, lab coat and safety goggles. Put up warning sign Collect samples only when they are cooled to room temperature | L |
| 4.1.5 | Contact with hydrochloric acid and nitric acid | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.1.6 | Not available | | | | | | |
| 4.1.7 | Contact with sulfuric acid | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.1.8 | Contact with hydrochloric acid | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| FINAL ASSESSMENT: User can protect themselves with proper training and take precaution | | | | | OVERALL RISK: | | M |

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability–Unlikely:1; Possible:2; Very Likely: 3

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.2** Solvent Extraction) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.2.1 | Contact with hydrochloric acid and toluene | Skin, eye and respiratory irritation. Toxic to health if swallowed or breathed in. | H | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | L |
| 4.2.2 | Not available | | | | | | |
| 4.2.3 | Contact with ethanol, butanol, acetone, benzene, or hexane | Skin, eye and respiratory irritation. Toxic to health if swallowed or breathed in. | H | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | L |
| 4.2.4 | Contact with hydrochloric acid and nitric acid | Skin, eye and respiratory irritation. Toxic to health if swallowed or breathed in. | H | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | L |
| 4.2.5 | Not available | | | | | | |
| 4.2.6 | Contact with hydrochloric acid, nitric acid, acetone and hexane | Skin, eye and respiratory irritation. Toxic to health if swallowed or breathed in. | H | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | L |
| FINAL ASSESSMENT: 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–Unlikely:1; Possible:2; Very Likely: 3.

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.3** Chromatography separation) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.3.1 | Break of glass apparatus | scratch on skin | L | L | L | be careful with placing and handling those instruments | L |
| 4.3.2 | Not available | | | | | | |
| 4.3.3 | Not available | | | | | | |
| 4.3.4 | Not available | | | | | | |
| FINAL ASSESSMENT: 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–Unlikely:1; Possible:2; Very Likely: 3.

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.4** Electrolysis) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.4.1 | Not available | | | | | | |
| 4.4.2 | Contact with agarose | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.4.3 | Hot solution from microwave | Burned skin | M | M | M | Wear heat protective gloves, lab coat and safety goggles. Put up warning sign Collect samples only when they are cooled to room temperature | L |
| 4.4.4 | Not available | | | | | | |
| 4.4.5 | Not available | | | | | | |
| 4.4.6 | Not available | | | | | | |
| 4.4.7 | Electronic device | Electric shock | M | L | L | Keep hands dry, wear insulated gloves | L |
| 4.4.8 | Not available | | | | | | |
| 4.4.9 | Not available | | | | | | |
| 4.4.10 | Contact with agarose | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.4.11 | Not available | | | | | | |
| 4.4.12 | Contact with acrylamide or bisacrylamide | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.4.13 | Contact with butanol or ammonium persulfate. | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.4.14 | Not available | | | | | | |
| FINAL ASSESSMENT: User can protect themselves with proper training and take precaution | | | | | | OVERALL RISK: | M |

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability–Unlikely:1; Possible:2; Very Likely: 3.

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.5** Neutralization) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.5.1 | Contact with Sodium hydroxide | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.5.2 | Not available | | | | | | |
| 4.5.3 | Not available | | | | | | |
| 4.5.4 | Contact with Sodium hydroxide | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.5.5 | Contact with agarose | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| FINAL ASSESSMENT: User can protect themselves with proper training and take precaution | | | | | | OVERALL RISK: | M |

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability–Unlikely:1; Possible:2; Very Likely: 3.

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.6 Replacement reaction)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.6.1 | Not available | | | | | | |
| 4.6.2 | Not available | | | | | | |
| 4.6.3 | Not available | | | | | | |
| 4.6.4 | Not available | | | | | | |
| FINAL ASSESSMENT: 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–Unlikely:1; Possible:2; Very Likely: 3.

| **HAZOP Template**<br>**Hazard and Operability Analysis (4.7** Solvent Extraction) | | | | | | | |
|---|---|---|---|---|---|---|---|
| NO | HAZARD | HAZARD EFFECT | SEVERITY | PROBABILITY | RISK | MINIMISE RISK BY | RESIDUAL RISK |
| 4.7.1 | Contact with hydrogen peroxide | Skin, eye and respiratory irritation | M | H | H | Prepare stock solution and carry out reaction in fume hood. Always wear lab coat, gloves and safety goggles | M |
| 4.7.2 | Not available | | | | | | |
| 4.7.3 | Not available | | | | | | |
| FINAL ASSESSMENT: User can protect themselves with proper training and take precaution | | | | | | OVERALL RISK: | M |

Remark: Severity–Low:1 (Minor injuries, first aid); Medium:2 (Hospitalization, medical leave); High:3 (Serious injuries, fatality) Probability–Unlikely:1; Possible:2; Very Likely: 3.

## 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 |
| (9) | Sodium hydroxide | 30% | 250mL |
| (10) | Copper | 90% | 10g |
| (11) | ▪ ▪ ▪ Acrylamide | 90% | 100mL |
| (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