

Mercury, membrane or diaphragm

Tutor's guide

Context of the unit

This teaching resource is one of a set of units developed by the Chemistry Department and the Teaching and Learning Service Unit at the University of Glasgow and is intended to be used as part of the second year course. The aim of the unit is not to teach about electrochemistry but to illustrate some of the chemical and industrial issues associated with the selection of a suitable production process for chlorine, sodium hydroxide and hydrogen.

Aims of the unit

After completing the unit, students are expected to:

- (a) be aware of some of the chemical factors that influence the choice of a production scale reaction cell;
- (b) be aware of the significance of purity and costs in selecting an appropriate process;
- (c) be aware of the scale of operation and pollution implications of particular processes; and
- (d) accept that discussion and compromise are part of industrial decision taking.

By experiencing different views of the same issue, students are encouraged to recognise the many facets of real-life decision taking and to accept that decisions often have to be made on the basis of incomplete information. Students will also have opportunities to assess data presented in several forms, to weigh arguments, to contribute meaningfully to a group discussion, to present arguments based on gathered evidence and to listen to the arguments proposed by others.

How the unit operates

It is important that the students are allowed to interact in groups with the materials. The role of the tutor is that of **manager** rather than **teacher**.

Whole ITU Group → Sub-group → Design team

The main thrust of the unit is to get the students to work together in small units and to play the role of a design team optimising electrochemical cells for the industrial production of chlorine, sodium hydroxide and hydrogen. Three types of cell are currently in use and each design team looks at one type of cell. They are initially provided with a basic outline of the cell and asked to understand how the cell works. After a short period of time more

detail is made available to them and then sometime later a full description of the cell is given to them. Controlling the input of information is intended to make them think about how the cells work. Their main task is to explain the operation of the cells by means of a design team presentation. **(In essence the effective learning value of the unit is based around the adage: ‘you don’t fully understand something until you have to explain it to others’)**. Two presentations from two separate speakers (speaker one and speaker two) are required from the design teams. Speaker 1 will address the technical operation and principles of the cell. Speaker two will promote the advantages of cell against what is known about the other cells. A group discussion will then ensue to determine the best cell design. This will involve economic and environmental factors as well as straight electrochemistry. This sub-group discussion will be lead by the tutor but will be documented and summarised by speaker three. The topic will be reviewed by the whole class in the final session where speaker three will outline the main conclusions from each sub-group.

The unit is made up of 11 parts. This is presented schematically in *Figure A* and described below. A timetable for operation of the unit is presented in Table A. After an introductory talk the students are divided up into four sub-groups (A, B, C, D), which are then further sub-divided into design teams (A1, A2, A3, B1, B2, ... E2, E3). Small sub-groups (of 12) and design teams (of four) are intended to encourage discussion and participation between all the participants. As soon as you locate in the tutorial rooms assign the design teams (arbitrary) and locate the three design teams in different parts of the room.

1. Whole class. *Introduction to Unit 2*. Aims and structure of the unit. Video 1. Students given *Introduction sheet* (white paper).
2. Class divided into four groups (A, B, C, D) and relocate into smaller rooms (see tutor’s timetable).
3. The sub-groups are spilt into three design teams and asked to go through *Introduction sheet*. Allow five minutes reading time, five minutes to undertake Task 1 and five minutes to discuss the issues.
4. Working in the same design teams, give out copies of *Background information* (green paper). Allow approximately five minutes reading time. Tutor to highlight major issues then lay out approach for Task 2.
5. For each sub-group, give the design team a copy of one of the three briefing statements.
e.g. A1 -- *The mercury cell* (blue)
 A2 -- *The diaphragm cell* (pink)
 A3 -- *The membrane cell* (yellow)
 B1 -- *The mercury cell* (blue), etc.

Allow five minutes reading time and 10 minutes to discuss the issues within the small group. The groups will encounter difficulties so then provide them with sheet 4, *Further information*. Allow five mins reading time with further five mins group discussion. Then issue sheet 5, *Complete cell diagram*. Designate speakers one and two.

6. Allow up to 10 minutes for the design team to develop their viewpoints and to prepare for a brief technical presentation [One OHP sheet - provided] to be made to the sub-group (speaker one).
7. From the three technical presentations each design team is asked to sell/justify/market their own cell to the Company Technical Director (*i.e.* tutor). This can be done quite swiftly: 10 mins for the design team to agree a strategy and then a brief presentation to be made to the Technical Director and the other design teams.
8. The tutor is then asked to encourage a sub-group discussion where the best electrochemical cell is selected and the justification for that choice documented on an OHP acetate.
9. Return to main lecture theatre.
10. Plenary session: Speaker three to present summary for each sub-group. The four responses are collated and an overview is provided of the performance characteristics of the three cells. Video 2, slides and the *Summary sheet* (white).
11. Finally, students asked to fill out an assessment form (sheet 7, green paper).

De-briefing

In section 8, there is an opportunity to bring the three sub-sets of students together and chair an open discussion. This should be led by the tutor who should question the sub-group on their understanding of how each cell operates and the relative advantages. Tutor to get speaker three to fill in summary OHP. The group should reach a consensus for the best cell design.

In the plenary discussion the situation will be reviewed. A short video and slide presentation will show examples of working cells and provide an indication of the scale of operation. Future trends will be presented.

The total time required for the unit, including the de-briefing, is approximately two hours 40 mins.

Coursework

These interactive teaching units are considered to be an important part of the 2nd year programme and will be assessed. The students are required to write a one page (500 word) essay on the topic of the particular unit.

The interactive unit component represents 5% of the total assessment for both 2X and 2Y. Tutors are asked to mark the essays for their group, following a set marking scheme.

Main points

1. The whole class is divided into sub-groups of *ca* 12 students and headed by a tutor. The sub-group is further divided up into three 'design teams' of approximately four students each. Divide the students up into their design teams right at the beginning of the group session so they have the opportunity to interact together from the start.
2. Take a register of the sub-group using the attendance/mark sheet provided. Get the students to sign their name. This is necessary for marking purposes.
3. Two speakers (Speaker one and Speaker two) are required from each design team and an additional speaker (Speaker three) is required to represent views of the sub-group. Inform the sub-group right at the very beginning of the session of this requirement and try to nominate speakers early on in the proceedings. If necessary, use some random process to designate the speakers. The students are sometimes reluctant to volunteer themselves for oral presentations but they need to 'grasp the nettle' for the Unit to work properly.
4. Speakers one and two only need to present to the sub-group. Speaker one has to make a **technical presentation** on the chemical principals of a specific electrochemical cell. At this stage, the tutor should quiz the design team on aspects of the electrochemistry and operating principals of the cells. Understanding of the basic chemical equations (anode/cathode reactions) should be stressed. Speaker two has to present a case for why their cell should be selected to go into production – a **marketing presentation**. This latter presentation should include more economic and environmental issues. The tutor should question the design team on these matters. OHP acetates are provided to assist the presentations.
5. After the talks promoting the various electrochemical cells (Speaker two), the tutor is asked to initiate a discussion between all three design times (*i.e.* the whole sub-group) as to which cell the Company should select to go into production. The decision needs to be documented and justified (OHP acetates provided). Speaker three is required to represent the views of the sub-group to the whole class towards the end of the unit.
6. Tutors to inform the sub-group where their coursework is to be handed in.
7. Retrieve OHP acetates and pens, and reuse
8. Reconvene in main lecture theatre. Designated person from each group (Speaker three) to present their conclusions to whole class.
9. The marking scheme for assessment purposes will be circulated.. All scripts will be marked over an agreed timescale.
10. Good luck.

Discussion guide

Each sub-group (e.g. A1, A2 and A3) will give a brief outline showing how one cell operates:

First presentation	<i>Mercury cell</i>
Second presentation	<i>Diaphragm cell</i>
Third presentation	<i>Membrane cell</i>

Each presentation should last not longer than four minutes and the groups should use the OHP acetates provided.

After the final presentation, you should discuss.

- (a) Which cell is least expensive to operate ?
- (b) Which cell gives products of highest purity ?
- (c) Which cell would you recommend today for a new production unit ?

Characteristics	Cell		
	Mercury	Diaphragm	Membrane
<i>Cell separator</i>	None	Polymer, fused asbestos	Nafion
Method of separator application	None	Polymer fusion	Hanging sheet
Anode	DSA	DSA	DSA
Cathode	Mercury on steel	Steel	Nickel
Cell caustic Wt% NaOH	50%	12%	30%
Wt% NaCl	30 ppm	15% (150 000 ppm)	50 ppm
Electricity for electrolysis (kWh/ton of Cl)	3400	2900	2700
Energy for purification (kWh/ton of Cl)	-	700	250
Total energy requirement (kWh/ton of Cl)	3400	3600	2950

Recommendation:

Section	Exercise	<div style="text-align: center;"> LT (Whole class) </div>
1.	Introduction to class	<div style="display: flex; justify-content: space-around; font-weight: bold;"> A B C D E </div>
2.	Divide class and move to smaller rooms	<div style="display: flex; justify-content: space-around;"> ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ </div>
3.	Introduction to unit	<div style="display: flex; justify-content: space-around;"> A1 A2 A3 B1 B2 B3 C C C D D D E1 E2 E3 </div>
4.	Background information	<div style="display: flex; justify-content: space-around;"> ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ </div>
5.	Design teams	<div style="display: flex; justify-content: space-around;"> ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ </div>
6.	Sub-group presentations	<div style="display: flex; justify-content: space-around;"> A1 A2 A3 B1 B2 B3 C C C D D D E1 E2 E3 </div>
7.	Group presentations	<div style="display: flex; justify-content: space-around; font-weight: bold;"> A B C D E </div>
8.	Return to lecture theatre (LT)	<div style="display: flex; justify-content: space-around;"> ↓ ↓ ↓ ↓ ↓ </div>
9.	Plenary session	<div style="text-align: center; font-weight: bold;"> LT </div>
10.	Assessment	<div style="text-align: center; font-weight: bold;"> LT </div>