UNIT 1 The age of refrigeration

Tutor's guide

Context of the Unit
This teaching resource is one of a set of units devised by the chemistry department and the Teaching and Learning Service 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 the chemistry of refrigerants but to illustrate some of the chemical, industrial and ethical issues associated with the selection, production and use of refrigerants.

Objectives of the Unit
After completing the unit, students are expected to:

(a) be aware of the reasons behind the original choice of CFCs as refrigerants;
(b) be aware that the choice of a refrigerant depends on factors that are not just chemical;
(c) understand the types of compounds available for modern refrigerants;
(d) appreciate that chemical decisions may have an impact on a world scale;
(e) 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. They should begin to see the place of such skills in the context of the world of work.

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**.

As an example of the dynamic nature of the chemical industry, issues will be considered over a period of time. This unit is concerned with the production of refrigerants and examines critical issues in **1970**, **1987** and **1997**.

The unit is in **thirteen** parts. The structure of the unit is presented schematically in *Figure A*. After an introductory talk the students are divided up into four or five groups (A, B, C, D, E), which are then further sub-divided into three groups of approximately four students (A1, A2, A3, B1, B2, ... E2, E3). Small sub-groups are intended to encourage discussion between all the participants.

1. Whole class, in large lecture theatre. Introduction to Unit1. Aims and structure of the unit.
2. Class divided into five groups (A, B, C, D, E) and relocate into smaller rooms.
3. Groups are spilt into three sub-groups and given a copy of *Introduction* (white paper). Allow five minutes reading time, five minutes to undertake the tasks and five minutes to discuss the issues.
4. Working in the same sub-groups, give out copies of *Refrigerant choice* (blue paper). Allow approximately five minutes each for *Decisions 1 & 2* and the *Task*, five minutes for group discussion.
5. Now give out a copy of *Refrigerant Problems* (pink) and allow five minutes for reading and five minutes for group discussion.
6. For each group, give the sub-group a copy of one of the three briefing statements.
   e.g. A1 -- *CFC manufacturers* (pink)
   A2 -- *Refrigerator manufacturers* (green)
   A3 -- *Environmentalists* (yellow)

B1 -- CFC *manufacturers* (pink) *etc*.

7. Allow five minutes reading time and five minutes to discuss the issues within the small group. The *Replacing CFCs* acetate defines their tasks. Identify spokespersons one and two for each sub-group. Allow up to 20 minutes for the small group to develop their viewpoints and to prepare for a brief presentation [One OHP sheet and pen provided].
8. The *Review of sub-group position* acetate defines new tasks. Sub-group discussion with spokesperson two presenting OHP2.
9. Group discussion and review. Identify group spokesperson and prepare OHP3.
10. Return to large lecture theatre. Groups A-E to summarise positions using OHP3.
11. Summary and completion of assessment form.

Debriefing

Sections seven, eight and nine are intended to get the students discussing the pertinent issues and to provide opportunities for presentations to small sized audiences. Discussion should be guided by the tutor who can adopt the role of regulator. A guide to this role is appended.

It is then helpful to outline what actually happened historically and to allow students to see what is happening today. This will be done in the plenary discussion. Information has been provided for this.

The total time required for the unit, including the debriefing, is three hours.

Coursework

These interactive teaching units are considered to be an important part of the second year programme and will be assessed. The students are required to write a one page (500 words) essay on the topic of the particular unit. For this unit it is: Prepare a briefing document for your local MP on the topic of *Refrigerants for the New Millennium*. 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.

Background information

In the first part (I*ntroduction*), students should consider the idea of molecular polarity and inter-molecular attractions as a way of rationalising the patterns in the enthalpy data. They should appreciate that using a refrigerant with a higher enthalpy of vaporisation would have advantages in reducing the amount of refrigerant required for a given amount of heat transfer.

In *Refrigerant choice*, students will end up eliminating most of the molecules leaving the CFC (dichlorodifluoromethane) as the likely favourite. In the early 1970s, there were no known reasons why such a choice posed any problems. *Refrigerant Problems* provides further evidence and it becomes clear that replacements for the CFCs are urgently needed. A likely second choice is the hydrochlorofluorohydrocarbon and, historically, there was a small use of such molecules. However, in certain applications, both ammonia and hydrocarbon mixtures were employed

Students now are invited to <u>role play</u> the three main groupings that have a stake in finding the right replacements for CFCs. There are no simple answers and, indeed, different solutions may be relevant in different applications: for example, the best refrigerant for a domestic refrigerator may well not be the best for an industrial cold storage unit.

In the debriefing, there are opportunities to illustrate the way decisions are taken on the best available evidence and that further evidence may alter decisions radically. Indeed, final outcomes may depend on value judgements as several sets of valid information are brought together and discussed.

Tutor's background notes

The regulator
The UK government, as a signatory to the Montreal Protocol, is the principle regulator, although it connects with organisations such as the European Union (EU) and the United Nations (UN). The Department for Environment and Rural Affairs (Defra) is the primary governmental agency, although it interacts with the Department of Trade and Industry (DTI) and the Environmental Agency (EA). Your task is to listen to the recommendations from three groups of approximately four students, to comment as you see fit and to lead an open discussion. The following background information **(as available in 1987)** is provided to assist you. A summary of the current situation will be presented to the students at the end of the unit.

Hydrofluorocarbons (HFCs)
These contain C-H bonds that are susceptible to attack by hydroxyl free radicals (present in the lower atmosphere). They do not pose a threat to stratospheric ozone because they are easily degraded and do not contain chlorine. The tropospheric (lower atmosphere) lifetime of CF_3CH_2F (HFC-134a) is 15 years which compares with 116 years for CCl_2F_2 (CFC-12). HFC-134a closely matches CFC-12 (a commonly used refrigerant) in terms of its physical properties. The toxicity of HFCs has not been fully established and will take five years for studies to be completed but the signs are looking good at the moment. The major CFC producers have agreed to fund an independent body to undertake this project to gain the precise data required. HFCs are greenhouse gases although their global warming potential is much less than that for CFCs. HFCs are not commercially available at the moment.

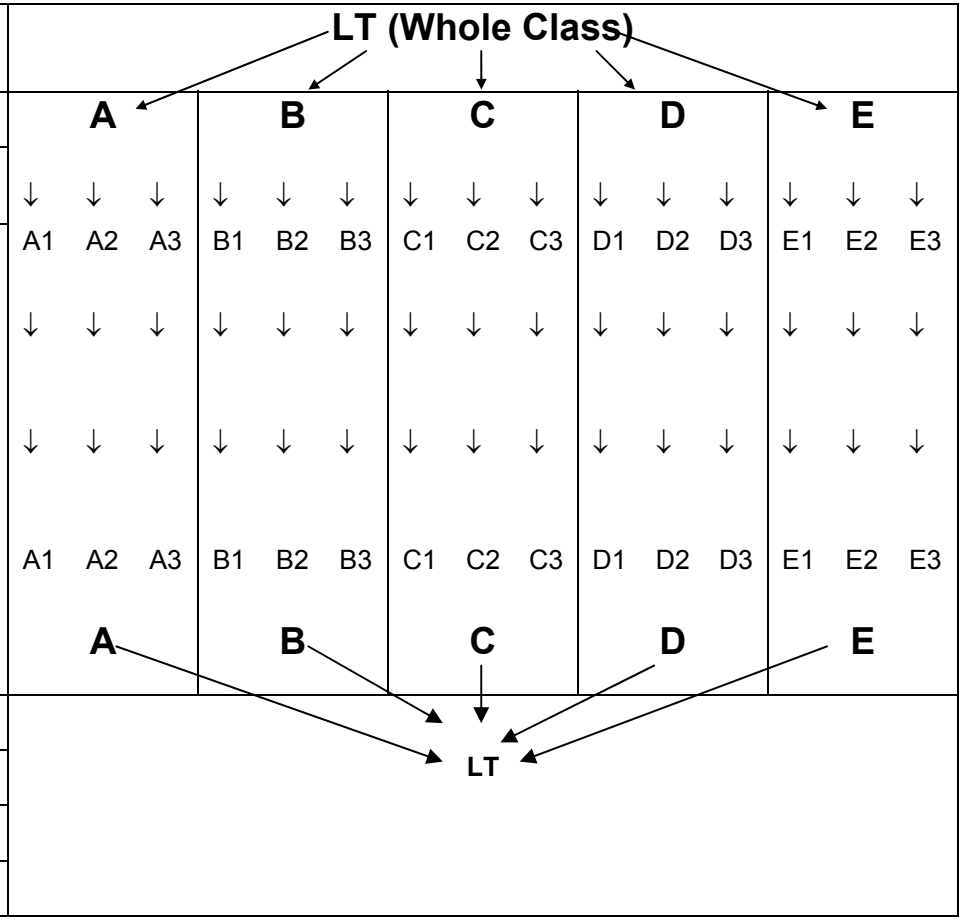
Hydrochlorofluorocarbons (HCFCs)
They can be regarded as a 'half way house' between CFCs and HFCs as they possess chlorine atoms and therefore have the potential to cause ozone depletion. The presence of C-H bonds makes them liable to degradation; consequently they have relatively short atmospheric lifetimes. In 1987 the Montreal Protocol did not regulate against HCFCs, but they are likely to be banned from use in the future. Most HCFCs are non-toxic and non-flammable. Some HCFCs are commercially available at the moment – *e.g.* HCFC-22. This enables manufacturers to assess their use in refrigeration systems where they are not used at present. HCFCs will be needed to aid the transition from CFCs to more environmentally friendly alternatives but would later (1990) be seen as being useful in the short term.

Inorganic substances
The best example of an inorganic substance that has good physical properties for use as a refrigerant is ammonia (NH_3). It is still used in large industrial and low temperature refrigeration systems. It represents a toxic hazard and is flammable in air. The extra capital investment necessary in equipment is offset on the large scale because of operating efficiencies. It does not deplete ozone and has a negligible global warming potential. CFCs were introduced in the 1930s as non- toxic, non -flammable replacements for substances such as ammonia and sulfur dioxide, which were in widespread use at the time.

Hydrocarbons
Propane, *n*-butane and *iso*-butane are the most applicable hydrocarbons for refrigeration. They can be used individually or as mixtures to cover different applications but need to be of very high purity to avoid corrosion and degradation problems. All hydrocarbons suitable for refrigeration purposes act as anaesthetics to varying degrees and are considered mildly toxic because of this. Long term effects are not fully established at the moment requiring further studies to be made. A major drawback is their flammability. Hydrocarbons do not affect the ozone layer and they possess insignificant global warming potential, the latter being due to their short atmospheric lifetime. However, volatile organic compounds (VOCs) such as hydrocarbons can adversely affect both human health and the environment when present in the lower atmosphere.

Figure A Unit 1 Class Distribution

Section	Exercise
1	Introduction to class.
2	Divide class into sub-groups and move to smaller rooms
3	Introduction to unit (white sheets)
4	*Refrigerant choice*
5	*Refrigerant problems*
6	Sub-group Briefing Statements
7	*Replacing CFC's* Sub-group presentation 1, OHP 1
8	Review of sub-group position Sub-group presentation 2, OHP 2
9	Group discussion Preparation of group summary, OHP 3
10	Return to LT
11	Group presentations, OHP 3
12	*Current state of affairs*
13	Assessment



Unit 1 timetable

Table A

This timetable is meant as an exemplar of the timings involved.

Time	Section	Exercise	Duration (mins)
14.00	1	Introduction to class in large lecture theatre.	15
14.15	2	Divide class into sub-groups A, B, C and D and move to smaller rooms	5
14.20	3	*Introduction to unit* (white sheets) Read Exercise Discuss	 5 5 5
14.35	4	*Refrigerant choice* (blue sheets) Read Tasks 1, 2, 3 Discuss	 5 5 5
14.50	5	*Refrigerant problems* (pink sheets) Read Discuss	 5 5
15.00	6	Briefing Statements *CFC manufacturers* (blue sheet) *Refrigerator manufacturers* (green sheet) *Environmentalists* Read Discuss Prepare Presentation	 5 5 5
15.25	7	*Replacing CFC's* Sub-group presentation one, OHP 1	 15
15.40	8	Review of sub-group Position Preparation Sub-group presentation two , OHP 2	 10 20
16.10	9	Group Discussion Preparation of group summary, OHP 3	10 5
16.25	10	Return to lecture theatre Plenary session	 5
16.30	11	Group presentation, OHP 3	10
16.40	12	Current state of affairs	10
16.50	13	Assessment	5
16.55	14	End	

Notes

1. The timetable is structured to move fairly quickly through the introductory sheets/exercises and leave sufficient time for the group discussions/presentations. Three presentations are required (OHP1-3). OHP 2 is intended to get the sub-groups to realise (*i*) who they are answerable to; (*ii*) their sphere of influence and (*iii*) their likely objectives.

2. Divide the students up into their sub-groups (*ca* four) right at the beginning of the group session so they have the opportunity to interact together from the start. Let the students know two members of the sub-groups will have to make a presentation (OHP1 and OHP2).

3. Take a register of the group using the attached mark sheet. Get the students to sign the sheet. This is necessary for marking purposes.

4. The Unit is made up of a series of 'tutorial sessions', presented as a function of time, *viz.* **1970, 1987, 1997**. Tutor to summarise position at end of each session.

5. For Sections three & four, let the students work through the problems in their sub-groups but then, using the OHP acetate provided, bring the whole group together to work through the answers.

6. Refrigerant Problems (Section five) identifies the need to replace CFCs.

7. Sub-groups to make presentation to Regulator and whole group on basis of Briefing Statements. OHP1. Spokesperson one.

8. On the basis of the OHP1 presentations, each sub-group is asked to review their position. Second presentation, based around OHP2. Spokesperson two.

9. Tutor to lead discussion to consensus on best replacement refrigerant. Prepare group OHP acetate (OHP3). Designate a body to summarise group views to the whole class.

10. Tutors to inform their group where their coursework is to be handed in.

11. All OHP acetates and pens should be returned to the main lecture. The used OHP acetates will be recycled. Any unused sheets that you have left over should also be reused.

12. Reconvene in main lecture theatre as per the timetable. The assigned person from each group (Spokesperson three) should present their conclusions to whole class.

13. Good luck.