# Industrial Gases

*Contents:* Reading, questions and data analysis concerning the production and uses of industrial gases.

*Time:* 2 periods. Could be used for homework.

*Intended use:* GCSE Chemistry and Integrated Science. Links with work on the properties, manufacture and uses of oxygen, nitrogen, argon, helium and hydrogen, and the composition of air. Particularly useful for revision work on gases.

*Aims:*

- To complement and revise prior work on the properties, manufacture and uses of gases
- To show some of the uses of major industrial gases
- To develop awareness of some of the economic factors influencing the manufacture, distribution and use of industrial gases
- To provide opportunities to practise skills in data analysis and the retrieval of information.

*Requirements:* Students' worksheets No. 408

## Suggested use of the unit

It is intended that Part 1 should be used to revise work on properties of the gases and establish some of their important properties. This should be tackled before students look at Part 2 and the Factsheet. Some of the information in Table 1 will need to be given by the teacher, unless students are given access to data books.

Alternatively, if time is short, the teacher may prefer to omit Part 1 and go straight on to Part 2.

**Data for Table 1**

| *Name of gas* | *Oxygen* | *Nitrogen* | *Hydrogen* | *Argon* | *Helium* |
|---|---|---|---|---|---|
| Formula | $O_2$ | $N_2$ | $H_2$ | Ar | He |
| Percentage of gas present in air | 21 | 78 | 0.001 | 0.9 | 0.0005 |
| Colour | colourless | colourless | colourless | colourless | colourless |
| Odour | odourless | odourless | odourless | odourless | odourless |
| Does it burn? | no | no | yes | no | no |
| Does it allow things to burn in it? | yes | no | no | no | no |
| Boiling point | −183°C | −196°C | −253°C | −186°C | −269°C |
| Relative molecular mass | 32 | 28 | 2 | 40 | 4 |
| Heavier or lighter than air? | heavier | lighter | lighter | heavier | lighter |

## Notes on the Factsheet

It should be noted that the prices are for gases in cylinders. Gas bought in the bulk liquid form tends to be much cheaper. No mention is made of the use of nitrogen and hydrogen to make ammonia, since the process normally uses air and natural gas to produce the gases *in situ*, rather than employing the pure, separate gases.

## Notes on some of the questions

*Q.7* The relative costs of nitrogen, oxygen, argon and helium correlate well with their abundance and production level, though it should be noted that price will itself determine demand, and hence influence the scale on which the gas is produced.

*Qs 9 to 11* A major industrial gas like nitrogen is a fairly low value commodity with a high production volume. It is necessary to keep distribution costs low by ensuring that all customers are within a 300 km distribution radius from a production plant. An added factor is the heavy containment equipment (cylinders or heavy steel tankers) needed for the gas.

*Q.14* In general, nitrogen is used in preference to the more expensive argon whenever possible. However, the tendency of nitrogen to react at high temperatures means that for applications such as welding or electric light bulbs, argon is preferred.

*Q.15* Students may find this question difficult. It is intended to explore:
(a) the problems of breathing pure oxygen under pressure, leading to 'oxygen poisoning' due to increased metabolic rate; and
(b) the fact that solubility of nitrogen can lead to 'the bends' when the diver is depressurized.

*Q.16* The low reactivity of nitrogen is the main factor here: by excluding oxygen, food spoilage reactions are inhibited.

*Acknowledgements* Figures 2, 5 and 6 supplied by Air Products; Figure 4 by courtesy of Thames Water.

# INDUSTRIAL GASES

Most of the gases you meet in the science laboratory also have important industrial uses. In this unit you will be looking at five of the major industrial gases. The gases are oxygen, nitrogen, hydrogen, argon and helium. How are they manufactured, what are they used for — and what do they cost?

You may have cylinders of gases in your school laboratories. These gases will have been supplied by one of the two large British industrial gas manufacturers — Air Products and British Oxygen.

Gas cylinders are colour-coded, according to the gas they contain (Figure 1).

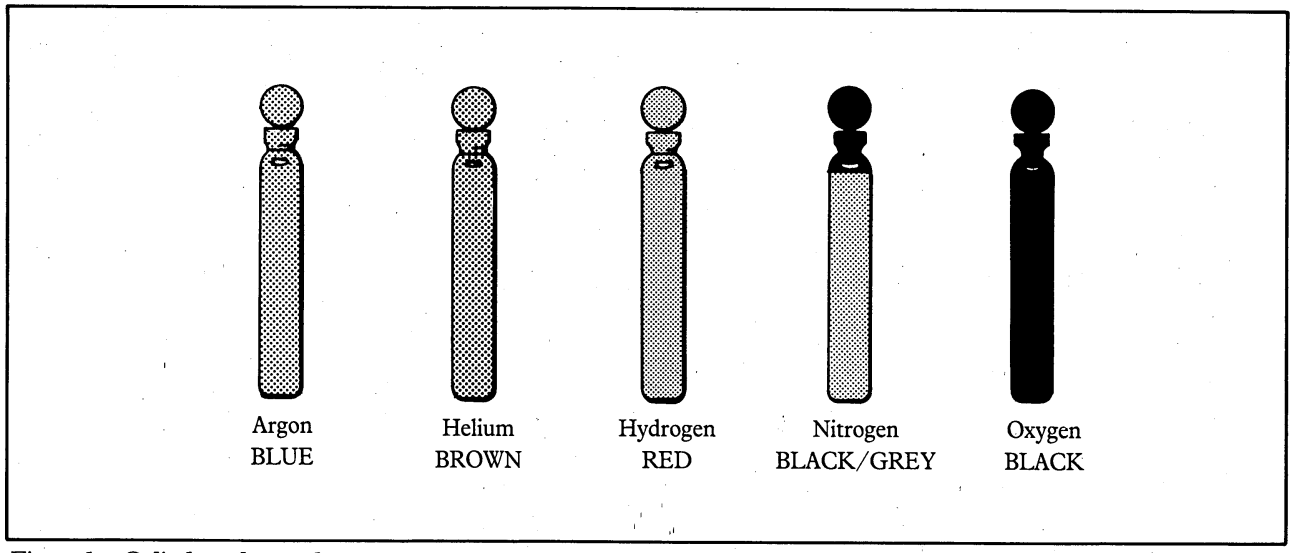


*Figure 1 Cylinder colour codes*

Buying gas in cylinders is quite expensive. For many large industrial uses, the gas is sold by the tanker-full. You have probably seen road tankers like the one in Figure 2. These tankers usually carry the gas in a liquid form. For really large-scale use, it is cheapest to make the gas on-site. For example, a steelworks might have its own oxygen-making plant.


*Figure 2 A gas road tanker*

## Part 1 Properties of the gases

Before we look at the industrial uses of the gases, we will consider some of the properties of each.

Make a copy of Table 1. Then fill in as much information as you can about each gas.

*Table 1 Basic properties of the gases*

| *Name of gas* | *Oxygen* | *Nitrogen* | *Hydrogen* | *Argon* | *Helium* |
|---|---|---|---|---|---|
| Formula | | | | | |
| Percentage of gas present in air | | | | | |
| Colour | | | | | |
| Odour | | | | | |
| Does it burn? | | | | | |
| Does it allow things to burn in it? | | | | | |
| Boiling point | | | | | |
| Relative molecular mass | | | | | |
| Heavier or lighter than air? | | | | | |

When you have filled in as much as you can, get any missing information from your teacher.

Before going on to Part 2, answer questions 1 to 5.

*Questions*

1 *For as many of the gases as you can, give the* source *from which it is manufactured. If possible, explain* how *it is manufactured from that source.*

2 *Which two gases could together be used for rocket fuel?*

3 *Which gases could be used for filling lighter-than-air balloons? Which gas would be* safest *for that purpose?*

4 *When metals are welded they get very hot. An 'inert atmosphere' is needed to stop the metal oxidizing. Which gases could be used to provide this inert atmosphere?*

5 *Which gas is used to remove impurities from iron during steelmaking?*

## Part 2 Industrial gases in use

The Factsheet gives information about each of the gases. First, use the Factsheet to check your answers to the questions in Part 1.

Then attempt the questions and activities below. Use the Factsheet to help you.

### 1 Costs of gases

*Questions*

6 *Present the costs of the gases in a way that makes it easy to compare them. (For example, you might draw a bar chart.) The cost of a gas depends on several factors. Three of the most important factors are:*
*(a) How abundant is the gas? The commoner the gas, the cheaper it is likely to be.*
*(b) How easy is it to get the pure gas from its source?*
*(c) What is the demand for the gas? Gases can be produced more cheaply in large quantities.*

7 *(a) Compare the costs of nitrogen, oxygen and argon. Try to explain the differences.*
*(b) Compare the costs of argon and helium, and try to explain the difference.*

8 *Compare the figures for amounts of the gases used per day. Classify each gas as low, medium or high level of use, relative to the others. Then try to explain why each gas has that particular level of use.*

### 2 Production and distribution of the gases

Gases are usually produced at a factory and distributed to the users by road or rail. Figure 3 shows the places where nitrogen is produced in Britain by one of the big industrial gas manufacturers. Look at the map, then answer questions 9 to 12.

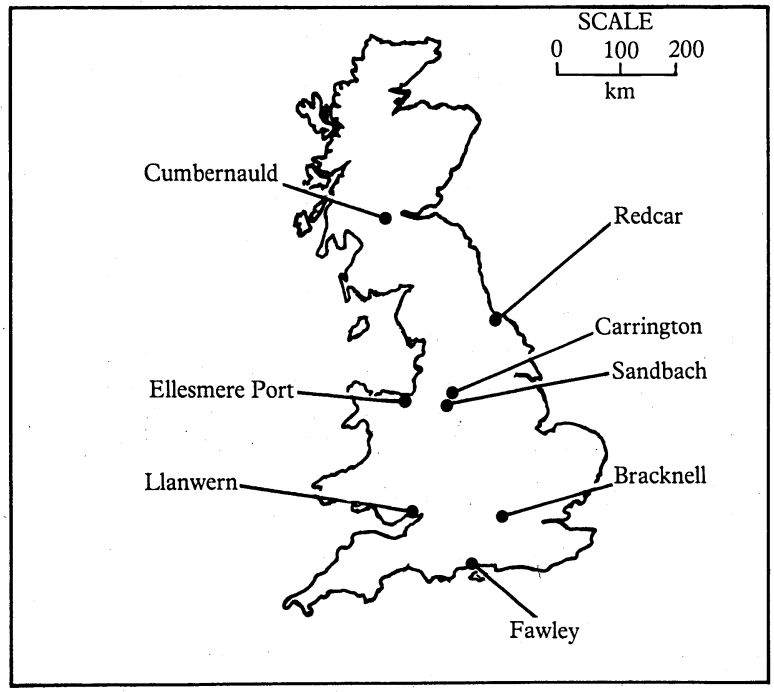


*Figure 3 A map showing the places where nitrogen is produced in Britain by one of the big gas manufacturers*

*Questions*

9 *Which part of Britain is furthest from a production plant?*

10 *Roughly how far would nitrogen have to be transported to reach a customer in that part of Britain?*

11 *Why does the company have several plants spread around Britain, instead of just a central one in, say, Birmingham?*

12 *Handling and transporting large amounts of compressed gases, such as nitrogen, oxygen and hydrogen, can cause safety problems. Suggest some possible hazards, and how they could be reduced.*

## 3 Uses of the gases

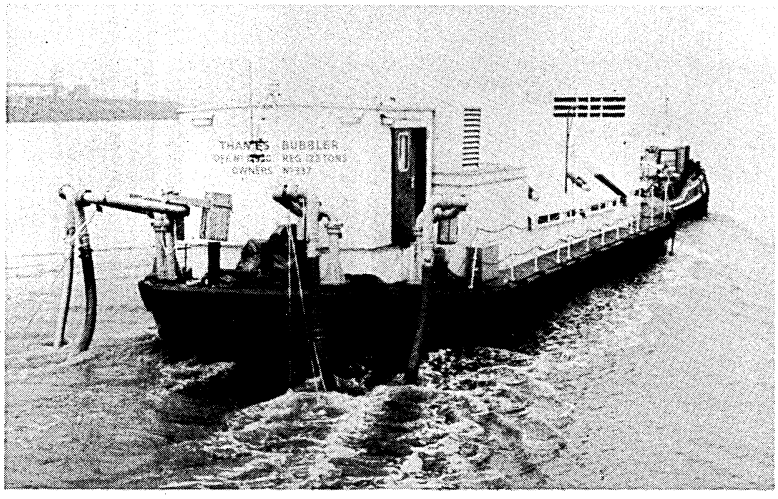


*Figure 4 The 'Thames Bubbler' protects aquatic life in the river in emergencies*

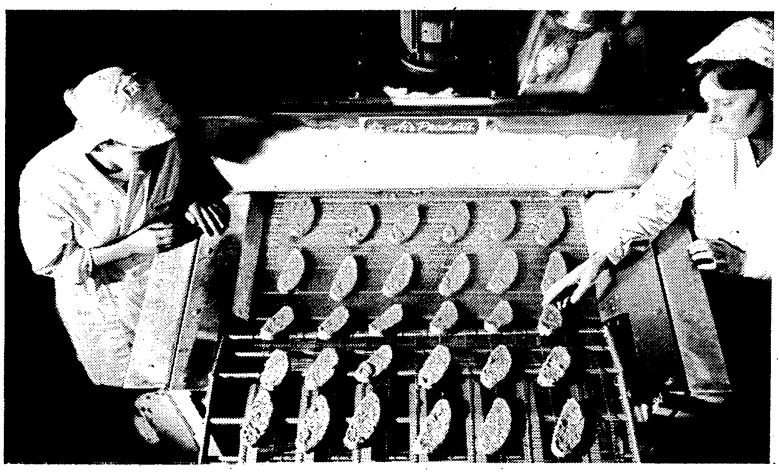

*Figure 5 Freezing food*

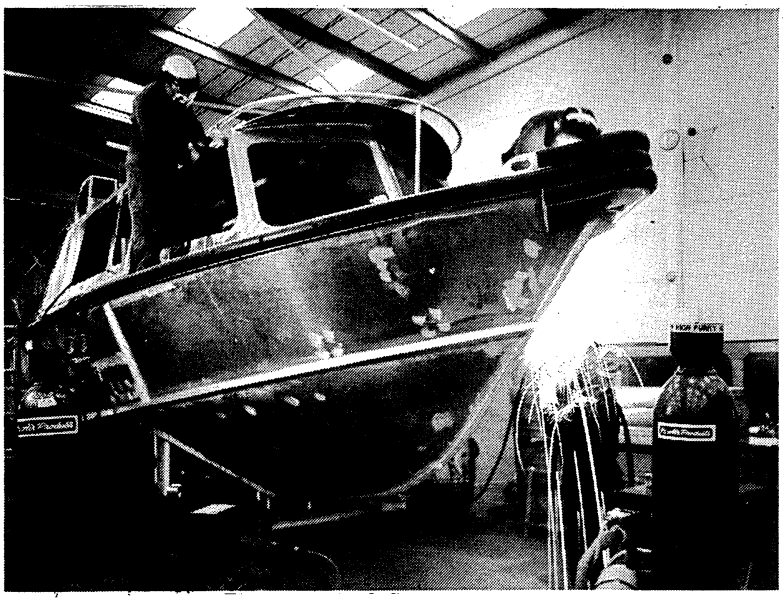

*Figure 6 Welding an aluminium boat*

*Questions*

*13 Which gas or gases are in use in each of the photographs in Figures 4, 5 and 6?*

*14 Nitrogen and argon are both used as unreactive gases. When might argon be more suitable than nitrogen? When might nitrogen be more suitable than argon? (Bear in mind the costs of the gases. Remember that nitrogen, unlike argon, is not* totally *unreactive.)*

*15 Helium is mixed with oxygen to give breathing gas for divers. Try to find out:*
*(a) Why oxygen is not used on on its own*
*(b) Why helium is used instead of nitrogen, even though nitrogen is much cheaper.*

*16 Why is liquid nitrogen more suitable for freezing food than liquid air or liquid oxygen? (The difference between their boiling points is too small to matter.)*

## Industrial Gases Factsheet

| *Gas* | *Source of the gas and how it is manufactured* | *Approximate cost of the gas bought in cylinders* | *Amount of gas used in U K in 1984 (tonnes per day)* | *Major uses of the gas* |
|---|---|---|---|---|
| **Oxygen** | Air. Manufactured by fractional distillation of liquid air. | £0.50 per cubic metre (volume measured at atmospheric pressure) | 11 000 | In steel making — used to remove impurities from iron by oxidizing them<br>In hospitals — for patients with breathing difficulties<br>For divers and high altitude climbers — as a breathing gas<br>For welding — an 'oxy-acetylene' flame is hot enough to melt metal<br>For treating sewage — oxygen helps micro-organisms to break down harmful materials<br>Combustion processes — oxygen enriched air makes fuels burn better |
| **Nitrogen** | Air. Manufactured by fractional distillation of liquid air. | £0.50 per cubic metre | 4 000 | For freezing — liquid nitrogen is so cold (−196°C) it can be used to freeze food and biological material in order to preserve them<br>As an unreactive atmosphere — nitrogen is used as a cheap, unreactive gas 'blanket' to stop things reacting with air (for example, in petrol storage tanks and food packaging) |
| **Hydrogen** | As a by-product from the manufacture of other chemicals. For example, the manufacture of sodium hydroxide and chlorine also produces hydrogen. | £1.50 per cubic metre | 2 600 | As a fuel<br>In the refining of petroleum<br>For making margarine — hydrogen is used to turn oils to fats<br>In the treatment of metals |
| **Argon** | Air. Manufactured by fractional distillation of liquid air. | £2 per cubic metre | 300 | As an unreactive atmosphere — an inert gas 'blanket' to stop reaction with air (for example, inside light bulbs and in welding) |
| **Helium** | From natural gas wells in the USA. | £8 per cubic metre | 1.5 | As an unreactive gas — for mixing with oxygen in divers' breathing gas<br>As a lighter-than-air gas — for air balloons<br>For supercooling — liquid helium at −269°C is used to supercool magnets |