

## Metals as Resources

*Contents:* Data analysis exercises on the prices, abundance and reserve lifetimes of metals, and problems associated with their depletion.

*Time:* 2 periods or more, depending on number of parts attempted.

*Intended use:* GCSE Chemistry and Integrated Science. Links with work on reactivity, abundance, extraction and uses of metals.

*Aims:*

- To complement and revise prior work on metals and the reactivity series, and the extraction and uses of metals
- To show some of the factors affecting the price of metals
- To develop awareness of the finite nature of metal resources, and the desirability of encouraging replacement and recycling
- To provide opportunities to practise data analysis skills.

*Requirements:* Students' worksheets No. 604. If possible a copy or copies of newspapers giving current metal prices (for example *Financial Times*, *The Times*)

The unit is best used after some coverage of metal occurrence, extraction and the reactivity series. The class could usefully be divided into small groups to discuss the questions. Teachers may well wish to invent questions of their own based on the data. If possible, students should have an opportunity to check the metal prices in the unit against those in the financial pages of a current newspaper. This adds interest and immediacy to the exercise, and differences may lead to fruitful discussion.

The unit is in three parts, each fairly self-contained. It is not necessary to use all three parts, though they do complement one another.

Part 1 Production and prices

Part 2 Reserves and resources

Part 3 What happens when supplies run out?

### Notes on some of the questions

*Q.1* The first six metals in order of production quantity are: Fe, Al, Cu, Mn, Zn, Cr.

*Q.2* The lowest production is for gold, mainly, of course, because of its rarity.

*Q.5* The least abundant metals are generally the most expensive. The converse is not necessarily true, because for highly abundant metals like iron and aluminium, extraction cost becomes important.

*Q.7*

(a) Gold is more expensive than silver because of its lower abundance.

(b) Aluminium is more expensive than iron because of its higher reactivity and consequently greater extraction cost. The fact that aluminium has to be extracted electrolytically, and the fact that it forms 3+ ions, make extraction costs high.

(c) Copper is more expensive than aluminium because of its lower abundance.

**Q.8** It is important to stress that metal prices are very sensitive and are determined by many factors in addition to abundance and reactivity. These include:

- Supply and demand. This is a most important and powerful factor, as can be seen by the fluctuations of metal prices from day to day.
- Political factors. The prices of strategic metals, particularly gold, are sensitive to world events. For example, the price of gold may rise at times of political tension, because of gold's importance as a backing for currency.
- Cost of processing ore (likely to be related to abundance). Country of production (labour costs, transport costs, etc.).

**Q.10** There is an opportunity here to explore the whole question of the exploitation of developing countries' resources by industrialized developed countries, both at present and in the colonial past. Some developing countries' economies are heavily dependent on the export of minerals (for example, Jamaica with bauxite; Zambia and Zaire with copper) and this makes these countries vulnerable to price movements originating in industrialized countries. A further dimension is added by the position of South Africa as a major producer of many strategic minerals. The table below gives the major producing countries for some important metals.

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<i>Metal</i>	<i>Major producers of ore</i>
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Aluminium	Many countries including Jamaica, Guinea and Ghana
Chromium	South Africa, USSR
Cobalt	Zaire, Zambia
Copper	USA, Canada, USSR, Chile, Zaire, Zambia
Gold	USSR, South Africa
Iron	USSR, Australia, Scandinavia
Manganese	USSR, South Africa
Vanadium	South Africa, USSR

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**Q.12** Figures for reserves are constantly changing. One reason for this is the discovery of new reserves as old ones are used up. Reserves are also dependent on price: an increase in price of a metal may make it worth mining low-grade ores that were formerly uneconomic, and may hence increase reserves. The table below illustrates how the reserves of four metals have increased since the 1940s.

*World reserves of four metals/million tonnes*

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<i>Years</i>	<i>Cu</i>	<i>Pb</i>	<i>Zn</i>	<i>Al</i>
1940s	91	31 to 45	54 to 70	1605
1950s	124	45 to 54	77 to 86	3224
1960s	280	86	104	11 600
1970s	543	157	240	22 700

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However, it is important not to give a falsely optimistic impression; reserves really *will* run out one day, and students should be aware of the need for responsible use of mineral resources.

**Qs 13 and 14** The problem of recycling is largely an economic one, and for a low-value metal such as iron the problems of collection and separation, and the particular difficulty of recycling alloys, may make recycling uneconomic. However, students should appreciate that there are other factors to consider beyond the economic ones, for example, the environmental desirability of recycling.

*Q.15* 'Tonnage' uses of metals may decrease in the future, with, for example, more use of concrete instead of steel. However, falling demand for tonnage metals in developed countries is likely to be offset by increased demand in developing countries. It will be difficult to replace specialist metals in such applications as conductors and high-performance alloys for machine-tools, aircraft, etc.

### **Further resource materials**

The SATIS unit No. 310, *Recycling Aluminium*, takes further the whole question of recycling.

The Keep Britain Tidy Group Schools Research Project includes a useful unit, *Metals*. From: The Keep Britain Tidy Group, Bostel House, 37 West Street, Brighton, Sussex BN1 2RE.

*Acknowledgements* Figure 1 supplied by British Rail; Figure 2 supplied by Johnson Matthey Chemicals Ltd; Figure 3 supplied by COMPIX/Commonwealth Institute; Figure 6 is reproduced by permission of the Department of Trade and Industry.

## METALS AS RESOURCES

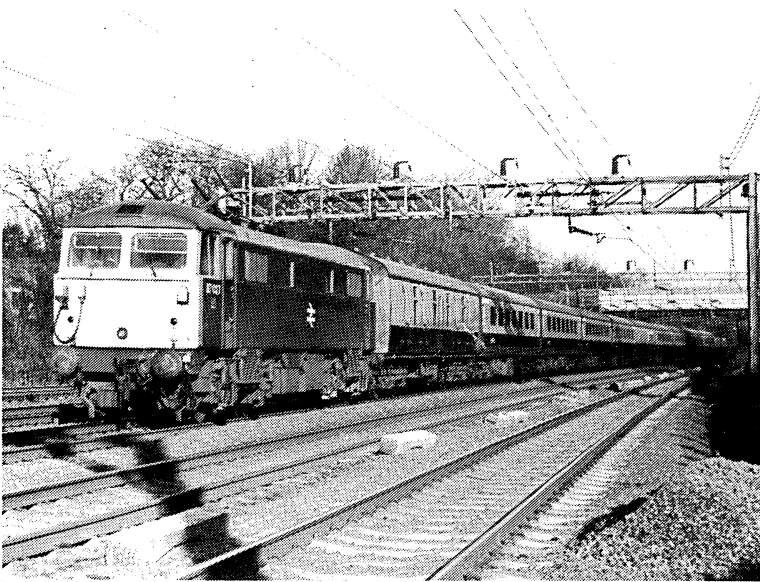
Metals have been used for thousands of years. More than sixty different metals are now extracted from the Earth and used by us. Each metal has its own properties which can be put to good use. These include strength, hardness, conduction of electricity, conduction of heat and individual chemical reactions.

As well as the pure metals, thousands of different mixtures of metals, called alloys, can be made. The alloys have their own properties, different from those of the original metals. This greatly extends the possible uses of metals.

Modern society depends heavily on metals. But how much of these vital resources do we have, and how long will they last?

This unit is in three parts:

- Part 1 Production and prices
- Part 2 Reserves and resources
- Part 3 What happens when supplies run out?



*Figure 1 Metal rails, metal wheels, metal wires overhead. Why are all these parts made from metals? Which parts could be replaced by non-metallic materials?*

## Part 1 Production and prices

### Production

Some metals are used much more than others. Table 1 shows the world production of metals in thousands of tonnes per year during the 1980s. The metals are listed in alphabetical order.

Look at Table 1, then answer questions 1 and 2.

*Table 1 World production of metals during the 1980s. The table lists the nineteen metals produced in the largest quantities, in alphabetical order.*

<i>Metal</i>	<i>Symbol</i>	<i>World production/thousand tonnes per year</i>
Aluminium	Al	12 700
Antimony	Sb	50
Arsenic	As	20
Chromium	Cr	6000
Cobalt	Co	30
Copper	Cu	8000
Gold	Au	1
Iron	Fe	400 000
Lead	Pb	3000
Magnesium	Mg	300
Manganese	Mn	8000
Molybdenum	Mo	100
Nickel	Ni	700
Silver	Ag	10
Tin	Sn	200
Tungsten	W	40
Uranium	U	40
Vanadium	V	30
Zinc	Zn	6000

### Questions

- Which six metals are produced in the largest amounts? List them in order with the largest first.
- Which of the metals in Table 1 is produced in the smallest amount? Suggest a reason why its production is small.



*Figure 2 Silver bars, 99.9 per cent pure. Worth about £5000 each at 1985 prices*

## Prices

The prices of metals vary widely. Table 2 gives the prices of a selection of important metals. The table also gives the percentage abundance of the metal in the Earth's crust. We might expect the most abundant metals to be cheapest.

Look at Table 2, then answer questions 3 to 5.

Table 2 Prices and percentage abundance of metals

Metal	Price per tonne (1985)	Abundance (% of Earth's crust)
Aluminium, Al	£750	8.1
Chromium, Cr	£3700	0.01
Copper, Cu	£1000	0.0055
Gold, Au	£8.6 million	0.0000004
Iron, Fe	£130	5
Lead, Pb	£290	0.0013
Silver, Ag	£150 000	0.000007
Tin, Sn	£9100	0.0002
Zinc, Zn	£500	0.007

### Questions

- 3 Arrange the metals in order of price, cheapest first.
- 4 Arrange the metals in order of abundance, most abundant first.
- 5 How well do the two lists from questions 3 and 4 match up? Are the least abundant metals generally the most expensive? Are the most abundant metals generally the cheapest? What important exceptions do you notice?

The price of metals does not just depend on their abundance in the Earth's crust. Most metals occur combined, as **ores**. The metal has to be **extracted** from the ore before it can be used. The more reactive metals are more difficult and expensive to extract from their ores. In the following list, the metals in Table 2 are placed in order of reactivity, with the most reactive first:

Aluminium, Al  
Zinc, Zn  
Chromium, Cr  
Iron, Fe  
Tin, Sn  
Lead, Pb  
Copper, Cu  
Silver, Ag  
Gold, Au

Answer questions 6 to 10 on the next page.

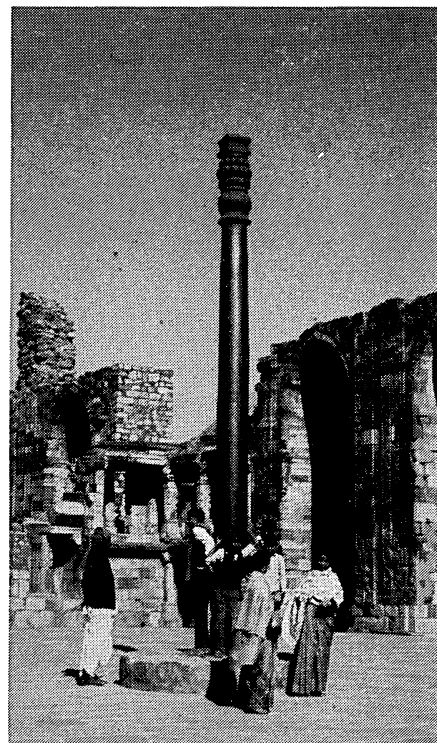


Figure 3 The Iron Pillar of Delhi. This remarkable piece of metalwork has stayed unrusty for over 1500 years.

### Questions

- 6 Does the list of metals in order of reactivity help to explain any of the exceptions you found in question 5?
- 7 Using Table 2 and the list that follows together, try to explain why:
- gold is more expensive than silver
  - aluminium is more expensive than iron
  - copper is more expensive than aluminium
- 8 Abundance and reactivity are not the only factors that affect the price of metals. What other factors do you think might be important?
- 9 Imagine a world in which gold and silver were cheap, but iron and aluminium were rare. What advantages and disadvantages would there be in (a) making a car from gold instead of iron; (b) making saucepans from silver instead of aluminium?
- 10 Aluminium is made from an ore called bauxite. A lot of bauxite comes from Jamaica. 75 per cent of Jamaica's exports are connected with bauxite. In the early 1980s, the recession in industrialized countries caused the price of aluminium to fall. This in turn caused unemployment and poverty in Jamaica. Explain why the fall in price of aluminium affected Jamaica in this way.

## Part 2 Reserves and resources

### How much is left?

The amount of metal ores in the Earth's crust is limited. We cannot go on digging them up for ever. Sooner or later there will not be enough left to be worth mining.

It is difficult to say how long our supplies of metals will last. This is because we cannot tell exactly how much ore there is under the ground, and how pure it is. The amount of a metal ore which we *know* is worth getting out is called the **reserve** of that ore. Figure 4 shows how long reserves will last for certain metals. The figures assume the metals will go on being used at the same rate as at present.

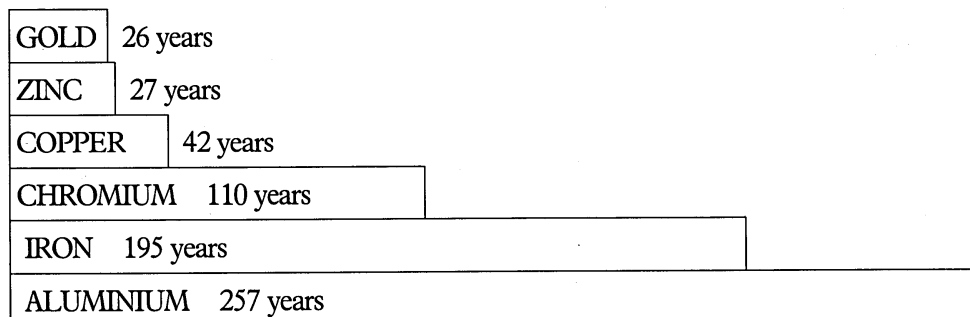


Figure 4 Lifetimes of reserves of some metals

The metals in Figure 4 should actually last longer than their reserve lifetimes. This is because there are probably supplies which we do not know about yet. The total supply of the metal, known and unknown, is called the **resources** of the metal. Figure 5 illustrates the difference between reserves and resources.

Answer questions 11 and 12.

### Questions

- 11 Reserves of aluminium are very high. Explain why.
- 12 Reserves of metals may actually increase with time, even though the metal is being used up. Suggest a reason why.

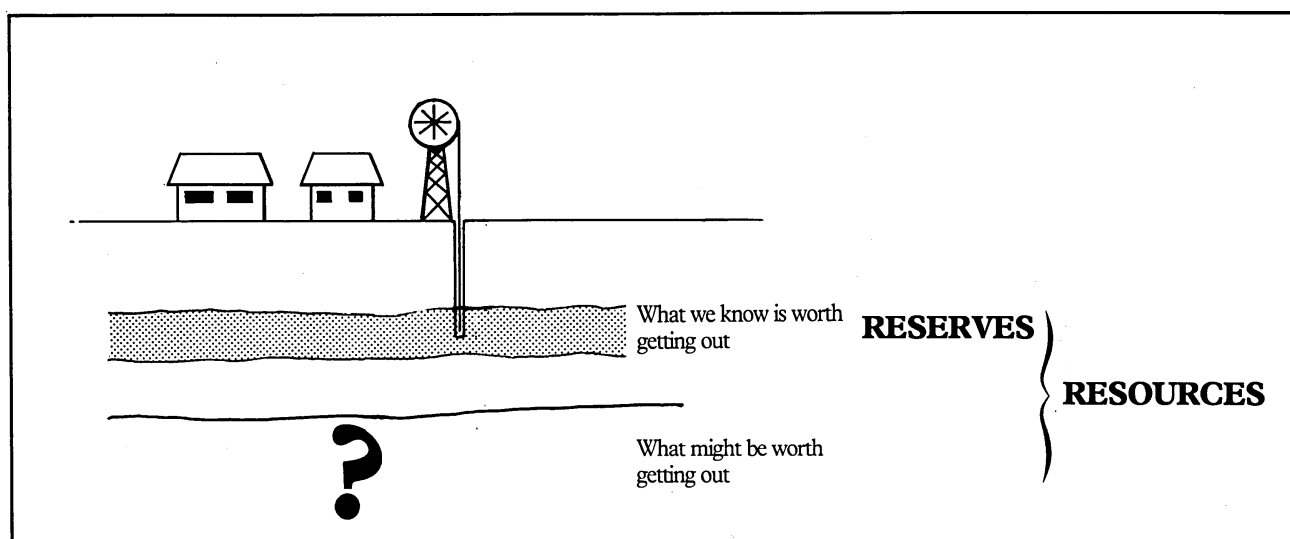


Figure 5 Reserves and resources

## Part 3 What happens when supplies run out?

Even though new reserves of metal ores are constantly being discovered, supplies must eventually run out. Long before then, we will need to look for ways round the problem. There are two important ways round the metal supply problem:

- 1 Recycling used metal
- 2 Using other materials instead of metals.

### 1 Recycling

Recycling means melting metal down and using it again. We already recycle used metal. Over 90 per cent of all the gold we use gets recycled, though only 50 per cent of iron is recycled. We can do more to recycle metals now, and in the future we will have to.



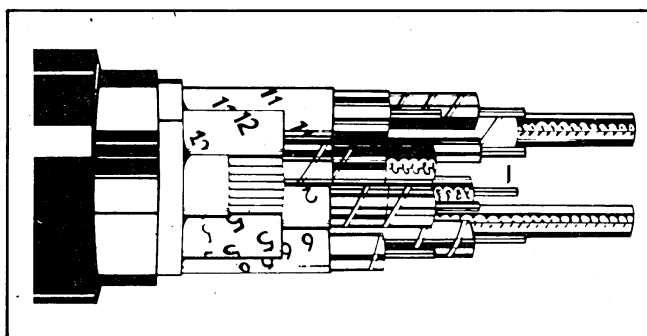
## 2 Using other materials instead of metals

Scientists are already finding new materials to replace metals. For example, copper can be replaced by plastic in pipes, and by optical fibres in telephone wires (Figure 6). Steel can be replaced by concrete for many uses, and aluminium can be replaced by plastic. But it is important to remember that eventually the replacements themselves may run out. For example, plastics are made from oil, and supplies of oil are limited.

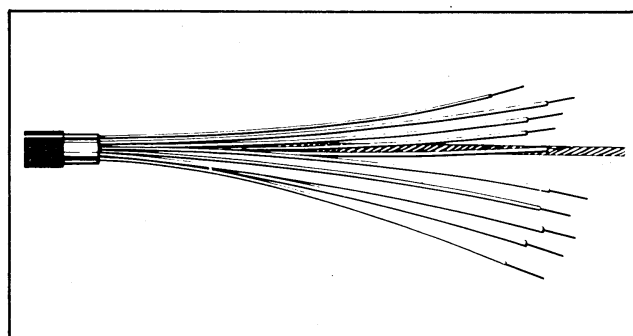
Answer questions 13 to 16.

### Questions

- 13 Explain why practically all the gold we use is recycled, but only half the iron is recycled.
- 14 What are the difficulties in recycling more of the iron we use?
- 15 For which uses do you think metals will be most difficult to replace?
- 16 Imagine world supplies of copper suddenly ran out. How would this affect your life?



Telephone cable with 10 000 call capacity —  
made from copper



Telephone cable with 10 000 call capacity —  
made from optical fibre

Figure 6