 Orders of magnitude

Specification references

* C10.1.1 Using the Earth’s resources and sustainable development
* MS 1b, 2h

Aims

This worksheet shows you how to carry out order of magnitude calculations to estimate answers to calculations and to evaluate the significance of data.

Learning outcomes

After completing this worksheet, you should be able to:

* extract and interpret information about the Earth’s resources from charts, graphs, and tables
* understand data and interpret information using orders of magnitude to compare.

Setting the scene

Order of magnitude calculations are used when the exact number is not crucial. Instead a rough approximation or estimate of the quantity is sufficient.

10 is an easy number to multiply or divide by so when carrying out order of magnitude calculations values are rounded to the closest power of 10.

|  |  |
| --- | --- |
| Power of 10 | Number |
|  10–3 | 0.001 |
|  10–2 | 0.01 |
|  10–1 | 0.1 |
| 100 | 1 |
| 101 | 10 |
| 102 | 100 |
| 103 | 1000 |

For example a mass of 8.8 g is rounded to 10 g.

Order of magnitude calculations are useful when a quick estimate of an answer is needed. They are also useful to check if a more precise value that has been calculated is reasonable.

To successfully complete this worksheet you will need to be familiar with writing numbers in standard form.

Worked examples

**Example 1**

A carbon atom has a diameter of 140 pm. Estimate the number of carbon atoms bonded side by side in a pencil lead of diameter 3 mm.

(1 pm  1 × 10–12 m)

Step 1:

Round 140 pm to the closest power of 10.

To the closest power of 10, 140 pm is 100 pm.

Step 2:

Round 3 mm to the closest power of 10.

To the closest power of 10, 3 mm is 1 mm.

Step 3:

Convert both rounded values to the same unit, in this case metres:

100 pm  100 × 10–12 m  1 × 10–10 m

1 mm  0.001 m or 1 × 10–3 m

Step 4:

Estimate how many times 1 × 10–10 m goes into 1 × 10–3 m

  1 × 107

Therefore, you can estimate that a typical pencil lead contains approximately 1 × 107 carbon atoms across its diameter.

**Example 2**

A student dissolves 0.21 g of NaHCO3 in 0.0125 dm3 of water. She calculates that the concentration of the solution produced is 17 g/dm3.

Use an order of magnitude calculation to show that the student’s answer is reasonable.

Step 1:

Round 0.21 g to the closest power of 10.

To the closest power of 10, 0.21 g is 0.1 g or 1 × 10–1 g

Step 2:

Round 0.0125 dm3 to the closest power of 10.

To the closest power of 10, 0.0125 dm3 is 0.01 dm3 or 1 × 10–2 dm3.

Step 3:

Complete the calculation using the rounded values.

concentration *(*g/dm3*)*  

concentration *(*g/dm3*)*   10 g/dm3

Step 4:

Round the student’s own answer of 17 g/dm3 to the closest power of 10.

To the closest power of 10, 17 g/dm3 is 10 g/dm3.

Therefore the student’s answer is reasonable.

Questions

1 Complete the following calculations involving numbers rounded to the closest power of 10. Express your answers in both decimal and standard form.

 a (1 × 103) × (1 × 10–5)

 (*2 marks*)

 b 

 (*2 marks*)

 c 0.1 × 10 000

 (*2 marks*)

 d 

 (*2 marks*)

2 Estimate the answers to the following calculations by carrying out order of magnitude calculations.

 a 0.26 × 890

 (*3 marks*)

 b 

 (*3 marks*)

 c 2010 × (2 × 10–5)

 (*3 marks*)

 d 

 (*3 marks*)

3 Crude oil is an important natural resource. It is used to make polymers and petrochemicals as well as supplying the petrol, diesel, and kerosene we need for transport. Carry out order of magnitude calculations to estimate the answers to questions **(a)–(d)**.

 a In 2013 the world consumption of oil was estimated at 3.3 × 1010 barrels per year.

 The world reserves of oil in 2013 were estimated as 1.324 × 1012 barrels.

 Estimate how many years the current reserves of oil will last assuming that consumption remains at the 2013 rate.

 (*3 marks*)

 b Sophie’s dad drives a petrol car. He travels approximately 19 500  miles per year. He estimates that he can drive 9 miles for every litre of petrol used as fuel.

 Estimate the amount of petrol in litres Sophie’s dad consumes per year.

 (*3 marks*)

 c Annual global production of the polymer poly(ethene) is estimated at 80 million tonnes. If there are 8760 hours in a year, estimate the amount of poly(ethene) produced in the world per hour.

 (*3 marks*)

 d The annual global production of jet fuel in 2010 was approximately 783 million litres.

 An aeroplane consumes 0.03 litres of jet fuel per passenger for every kilometre it flies.

 Estimate how many passengers could be transported from the UK to Australia each year (a distance of 15 223 km).

 (*5 marks*)

Student follow-up

1 This question is about the production of cotton.

 The table gives the population and annual cotton production of some different countries in 2012.

|  |  |  |
| --- | --- | --- |
| Country | Population | Annual production of cotton in tonnes) |
| China | 1 343 239 923 | 6 840 000 |
| India | 1 205 073 612 | 5 321 000 |
| US | 313 847 465 | 3 598 000 |
| Pakistan | 190 291 129 | 2 215 000 |
| Brazil | 205 716 890 | 1 638 103 |
| Turkey | 79 749 461 | 851 000 |
| Australia | 22 015 576 | 973 497 |
| Argentina | 42 192 494 | 210 000 |
| Turkmenistan | 5 054 828 | 198 000 |
| **World** | **7 057 075 000** | **25 955 096** |

 a By how many orders of magnitude is the population of India bigger than the population of Pakistan?

 (*4 marks*)

 b i Which country has the highest annual production of cotton?

 ii Carry out an order of magnitude calculation to estimate the annual production of cotton per person in Australia.

 (*3 marks*)

 iii If farmers harvest approximately 0.3 tonnes of cotton per acre of land per year, estimate how much land must be dedicated to cotton farms in the US.

 (*3 marks*)

 c Is cotton a finite or a renewable resource? Explain your answer.

 (*2 marks*)

Maths skills links

You will find it useful to be able to carry out a quick order of magnitude calculation for any calculation to check that your answer is reasonable.