F4 Modelling radioactive decay

This is the third lesson in an introductory course for post-16 chemistry learners covering key ideas in order of scale. Find out more about the course and approach here: **rsc.li/4kGyaoN**

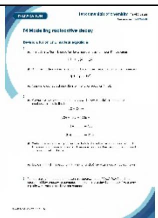
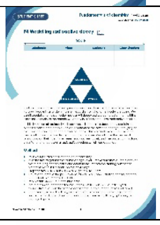
Before each lesson, ask learners to complete the preparation worksheet to revise knowledge from their 14–16 courses or previous lessons and introduce the topic for the lesson.

Then, get them to complete the student sheet during the lesson. It includes all key content and challenges misconceptions. Each student sheet has a scale and a Johnstone's triangle diagram at the top. Use these to help learners think about the relative scale of different aspects of chemistry and connect their understanding of sub-microscopic, macroscopic and symbolic representations.

This icon indicates that students will need access to learning materials e.g. textbook or online resources to support their learning. See **rsc.li/4eSiJIK** for links.

Begin each lesson by checking learners have completed the preparation work. Share the answers and ask learners to mark their own worksheets as part of their independent work.

Topics in this lesson

	Last lesson	F3 Nuclear fusion
	**Preparation worksheet**	Revision: fusion and nuclear equations Graph drawing
	**Lesson worksheet**	Modelling radioactive decay with pasta; radioactive half-life; alpha and beta particles; calculating decay
	Next lesson	F5 Light and electron energy levels

Materials

For the practical activity at the start of this lesson, provide each group with a cardboard tray and ~250 pieces of dried pasta.

Answers

Revision: fusion and nuclear equations

1.

(a) The correct equation is: ${}^{4}_{2}\mathrm{He} + {}^{12}_{6}\mathrm{C} \rightarrow {}^{16}_{8}\mathrm{O}$

(b) The numbers are on the wrong side of the symbol.
The numbers in the equation don't add up.

(c) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

2.

(a)

$${}^{12}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} \rightarrow \mathbf{{}^{13}_{7}N}$$

$${}^{21}_{10}\mathrm{Ne} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{24}_{12}\mathrm{Mg} + \mathbf{{}^{1}_{0}n}$$

$${}^{1}_{1}\mathrm{H} + \mathbf{{}^{6}_{3}Li} \rightarrow {}^{7}_{4}\mathrm{Be}$$

$${}^{1}_{1}\mathrm{H} + \mathbf{{}^{11}_{5}B} \rightarrow 3{}^{4}_{2}\mathrm{He} \qquad (3 \times 4 = 12;\ 3 \times 2 = 6)$$

(b) ${}^{3}_{2}\mathrm{He} + {}^{6}_{3}\mathrm{Li} \rightarrow 2{}^{4}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{p}$

(c) Two nuclei have joined to make a larger nucleus of a different element.

3. The nuclei are positively charged so they repel each other. A large amount of energy is required to overcome this.

Graph drawing

1. At least four points from the following:

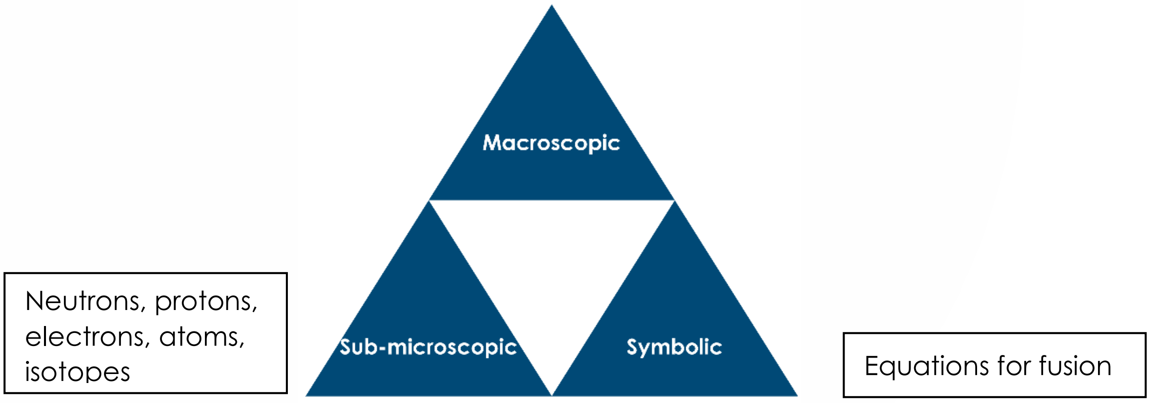
- the graph has no title
- the points are joined (not line of best fit)
- the axes are the wrong way round
- the x axis doesn't have units
- there is no label on the *y* axis
- the scales on both axes do not go up in even amounts
- the plotted line should go through the origin

2. Corrected graph following the guidance from question one.

Worksheet

Scale

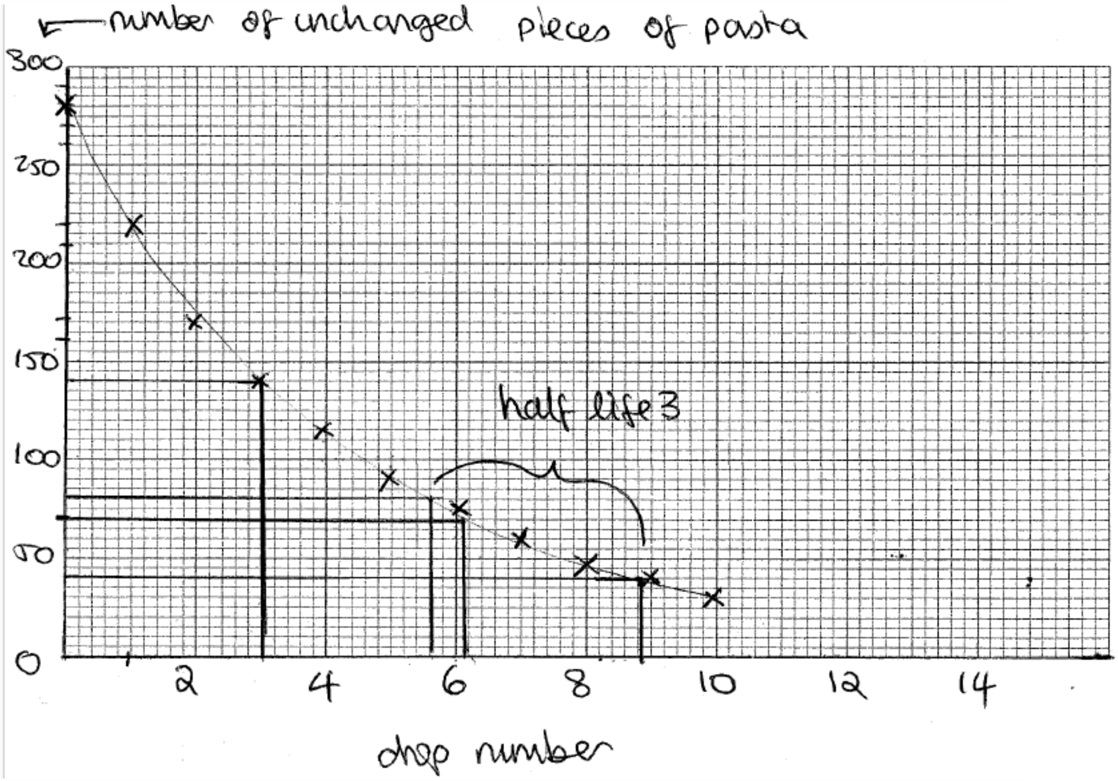
Subatomic	Atom	Molecule	Giant structure
Protons, neutrons, electrons	Fusion creating new nuclei		



Results: example class average data

Drop number	Unchanged pasta	Pasta removed
0	**278**	0
1	**218**	**60**
2	**171**	**47**
3	**138**	**33**
4	**113**	**25**
5	**92**	**21**
6	**74**	**18**
7	**58**	**16**
8	**48**	**10**
9	**38**	**10**
10	**30**	**8**

Example graph:



Questions on the data

1.

Half-life	Duration (drops)
1	3
2	6.1 – 3 = 3.1
3	8.8 – 5.6 = 2.8

2. They are broadly similar.

3. $^{4}_{2}\mathrm{He}$ or $^{4}_{2}\alpha$

4.

(a) $^{234}_{90}\mathrm{Th}$

(b) $^{217}_{85}\mathrm{At}$

(c) $^{226}_{88}\mathrm{Ra}$

5. $^{0}_{-1}\beta$

6.

(a) $^{90}_{39}\mathrm{Y}$

(b) $^{131}_{54}\mathrm{Xe}$

(c) $^{231}_{91}\mathrm{Pa}$

7.

$$^{232}_{90}\mathrm{Th} - 6\,^{4}_{2}\alpha - 4\,^{0}_{-1}\beta = \,^{208}_{82}\mathrm{Pb}$$

8.

(a) One half-life, therefore 16 g.

(b)

$\frac{78.8}{19.7} = 4$ half-lives

$\frac{32}{2^4} = 2\text{ g}$

or: 32 → 16 → 8 → 4 → 2
1 **2** **3** **4**

(c) 32 → 4 = 3 half-lives

4.5 x 10^{-4} seconds

(d)

$\frac{4.56\times10^4}{5.70\times10^3} = $ 8 half-lives

$\frac{32}{2^8} = 0.125\text{ g}$

or: 32 → 16 → 8 → 4 → 2 → 1 → 0.5 → 0.25 → 0.125
1 **2** **3** **4** **5** **6** **7** **8**

9.

(a) 36 → 9 = 2 half-lives x 5730 years = 11,460 years old

11460 – 2022 = 9438 BC

(b) The count rate is low, so is likely to be inaccurate. The half-life is very long so the age could be within a large range.