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Oxford Cambridge and RSA

GCSE (9–1)
Transition Guide

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259
For first teaching in 2016

KS3–KS4 Focus
Radioactivity

Version 1

www.ocr.org.uk/physics

Introduction

GCSE (9–1)

TWENTY FIRST CENTURY SCIENCE PHYSICS B

Key Stage 3 to 4 Transition guides focus on how a particular topic is covered at the different key stages and provide information on:

- Differences in the demand and approach at the different levels;
- Useful ways to think about the content at Key Stage 3 which will help prepare students for progression to Key Stage 4;
- Common student misconceptions in this topic.

Transition guides also contain links to a range of teaching activities that can be used to deliver the content at Key Stage 3 and 4 and are designed to be of use to teachers of both key stages. Central to the transition guide is a Checkpoint task which is specifically designed to help teachers determine whether students have developed deep conceptual understanding of the topic at Key Stage 3 and assess their 'readiness for progression' to Key Stage 4 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 3 teaching of the topic or by Key Stage 4 teachers to establish their students' conceptual starting point.

Key Stage 3 to 4 Transition Guides are written by experts with experience of teaching at both key stages.

Key Stage 3 Content

- a simple (Dalton) atomic model
- differences between atoms, elements and compounds
- atoms and molecules as particles
- fuels and energy resources

GCSE Content

- P5.1.1 describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus
- P5.1.2 describe how and why the atomic model has changed over time to include the main ideas of Dalton, Thomson, Rutherford and Bohr
- P5.1.3 recall the typical size (order of magnitude) of atoms and small molecules
- P5.1.4 recall that atomic nuclei are composed of both protons and neutrons, and that the nucleus of each element has a characteristic positive charge
- P5.1.5 recall that nuclei of the same element can differ in nuclear mass by having different numbers of neutrons, these are called isotopes
- P5.1.6 use the conventional representation to show the differences between isotopes, including their identity, charge and mass
- P5.1.7 recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays
- P5.1.8 relate emissions of alpha particles, beta particles, or neutrons, and gamma rays to possible changes in the mass or the charge of the nucleus, or both
- P5.1.9 use names and symbols of common nuclei and particles to write balanced equations that represent the emission of alpha, beta, gamma, and neutron radiations during radioactive decay M1b, M1c, M3c
- P5.1.10 explain the concept of half-life and how this is related to the random nature of radioactive decay M2e
- **P5.1.11 calculate the net decline, expressed as a ratio, in a radioactive emission after a given (integral) number of half-lives** M1c, M3d
- P5.1.12 interpret activity-time graphs to find the half-life of radioactive materials M1c, M2g, M4a, M4c
- P5.2.1 recall the differences in the penetration properties of alpha particles, beta particles and gamma rays
- P5.2.2 recall the differences between contamination and irradiation effects and compare the hazards associated with each of these
- P5.2.3 describe the different uses of nuclear radiations for exploration of internal organs, and for control or destruction of unwanted tissue
- P5.2.4 explain how ionising radiation can have hazardous effects, notably on human bodily tissues
- P5.2.5 explain why the hazards associated with radioactive material differ according to the radiation emitted and the half-life involved
- P5.3.1 recall that some nuclei are unstable and may split into two nuclei and that this is called nuclear fission
- P5.3.2 relate the energy released during nuclear fission to the emission of ionising radiation and the kinetic energy of the resulting particles
- P5.3.3 explain how nuclear fission can lead to further fission events in a chain reaction
- P5.3.4 describe the process of nuclear fusion and recall that in this process some of the mass may be converted into the energy of radiation

Comment

Of all the ideas and concepts to which learners are introduced at GCSE level, radioactivity is arguably the most new, and certainly the one that is most likely to challenge preconceptions based on what has been learned in other areas. Many of the confusions that arise when first introducing this subject are based on the fact that the real physics of what is going on is extremely complicated, and that most analogies that are approachable at this level involve simplifying the ideas to the point where many quite reasonable questions arise. For your more able learners it can be worthwhile extending their knowledge past the specification to clear up some of these questions, for instance, that while protons and neutrons can turn into each other, the nucleon number as a whole is conserved in these interactions. It is also important to remind learners that the electrons emitted in beta decay are not the ones from the shell of the atom; they are ones that have been created in the interaction that leads to neutrons turning into protons.

Part of the problem with this topic, even given this consideration, is catering both for the less advanced learners who may be put off by the complexity of the interactions and the profusion of particles and forces and phenomena, and might therefore lose confidence in dealing with the more practical areas of the topic. This could include discussions about nuclear power and the risks and dangers of radioactivity to humans, which are in many cases ideas that the population in general should have some grasp of in order to understand important issues relating to energy use, the environment, politics and so on. In this area, the question of exactly how much depth to go into has to be left to the discretion of the teacher. Remember that more engaged learners can always be encouraged to research the subject for themselves online.

In general, most learners are aware that there are areas of the subject that they do not yet know about and in which the complexity of the mathematics is simply too great to allow it to be part of the GCSE curriculum, and mentioning forces and concepts that they have not heard of before should not be too challenging for them.

Activities

Alpha Decay - Alpha Decay, Alpha Particles, Radioactivity
PhET – University of Colorado, Boulder
https://phet.colorado.edu/en/simulation/legacy/alpha-decay

A java interactive in which users can observe alpha decay in a small selection of atoms.

Beta Decay - Beta Decay, Radioactivity, Antineutrinos
PhET – University of Colorado, Boulder
https://phet.colorado.edu/en/simulation/legacy/beta-decay

A similar interactive to that above, this time dealing with beta decay.

Radioactivity
Contemporary Physics Education Project
http://www2.lbl.gov/abc/wallchart/chapters/03/0.html

A web page featuring a helpful summary of the basics of radioactive decay, with clickable links to pages about each main type of decay and other pages of related information.

Radioactivity: Expect the unexpected - Steve Weatherall
TED-Ed
https://www.youtube.com/watch?v=TJgc28csgV0

A video explaining the basics of radioactivity and some of its uses and dangers.

Overview

The learner tasks focus mainly on simple experiments to simulate half-lives using sweets and dice, going on to deal with ideas of how data is interpreted and how experiments are modelled, along with an introduction to the idea of radioactive dating. The idea is at least partly to give learners a sense that they are engaging fully with the ideas and not just performing tasks by rote. It may be a good opportunity to ask learners to analyse and explain their data and speculate on improvements to the experiment. They should be encouraged at all times to modify and improve any and all aspects of the experiment. For those learners who may not eat sweets, dice provide a perfectly good inedible alternative.

Teacher Preparation

The materials for this experiment are basically ordinary academic materials, plus sweets and dice. Dice can be purchased quite cheaply in large numbers. In addition, polyhedral dice with more than six faces as used in various types of games could be offered as an alternative; indeed, it is hoped that some learners might suggest their use.

Checkpoint task:

www.ocr.org.uk/Images/338056-radioactivity-checkpoint-task.doc

Activities

How Nuclear Power Works
HowStuffWorks
http://science.howstuffworks.com/nuclear-power.htm

A set of pages detailing the workings of a standard fission-based nuclear power station.

radioactive series
Brittanica.com
https://www.britannica.com/science/radioactive-series

A web page about decay chains/series, detailing the decay chains of uranium, neptunium, thorium and actinium.

Radon
Periodic Table of Videos
https://www.youtube.com/watch?v=mTuC_LrEfbU

An amusing and engaging video featuring and account of Rutherford's rivalry with William Ramsay and the discovery of radon, featuring some rather nice cloud chamber footage.

The Particle Adventure
http://particleadventure.org/decay_intro.html

A rather more in-depth account of the mechanisms behind radioactive processes, for more engaged learners.

Activities

Build an Atom - Atomic Structure, Atoms, Atomic Nuclei

PhET

https://phet.colorado.edu/en/simulation/build-an-atom

Another Java interactive from PhET. In this, users can build an atom from subatomic particles and see how stable/unstable it is, as well as it ionisation.

Why radioactivity occurs

Cyberphysics

http://www.cyberphysics.co.uk/topics/radioact/why.htm

A web page about the stability of various elements and the increasing ration of neutrons to protons as elements become heavier, and introducing worked examples of conversion from mass into energy.

Nuclear Lab (RADIOACTIVE)

Periodic Table of Videos

https://www.youtube.com/watch?v=NrIzWWmIboE

A video featuring a visit to a nuclear lab, featuring some interesting details about the working conditions and safety measures, and also an interesting bit of plutonium chemistry.

The `radioactive dice' experiment: why is the `half-life' slightly wrong?

IOPscience

http://hpc.ct.utfpr.edu.br/~charlie/docs/PPGEB/IMEDNUC/DICE_artigo.pdf

For braver learners or interested teachers, an account of why the measured "half-life" in an experiment to model radioactive decay with dice might not be the one you'd expect to observe in a substance with a decay constant of 1/6.

Resources, links and support

Science Spotlight – Our termly update Science Spotlight provides useful information and helps to support our Science teaching community. Science Spotlight is designed to keep you up-to-date with Science here at OCR, as well as to share information, news and resources. Each issue is packed full with a series of exciting articles across the whole range of our Science qualifications: www.ocr.org.uk/qualifications/by-subject/science/science-spotlight/

Find resources and qualification information through our science page: http://www.ocr.org.uk/qualifications/by-subject/science/

Contact the team: science@ocr.org.uk

Continue the discussion on the science community forum: http://social.ocr.org.uk/

and follow us on Twitter, @ocr_science

To find out more about GCSE and A Level reform please visit: http://www.ocr.org.uk/qualifications/gcse-and-a-level-reform

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