



Nuclear-based science benefiting all Australians

# Year 12 Investigating Science

Depth study guide

## Year 12 Investigating Science: Nuclear Science Depth Study

We recommend that an ANSTO excursion becomes the starting point for a nuclear science depth study. ANSTO's Year 12 Investigating Science excursion, together with the *ANSTO Year 12 Investigating Science Excursion Workbook*, helps students cover the following syllabus content:

### Module 6: Technologies

Students:

- Using examples, assess the impact that developments in scientific theories, laws and models have had on the development of new technologies, including but not limited to:
  - radioactivity and radioactive decay on the development of radiotherapy and nuclear bombs
- Using examples, assess the impact that developments in technologies have had on the accumulation of evidence for scientific theories, laws and models, including but not limited to:
  - technology to detect radioactivity and the development of atomic theory

### Module 8: Science and society

Students

- Investigate case studies of past events to consider how they have affected the public image of science, including but not limited to:
  - meltdowns of nuclear reactors
- Investigate and assess ethical issues surrounding current scientific research in, for example:
  - use of radiation
- Investigate the need for the regulation of scientific research in, for example:
  - products and processes of the nuclear industry
- Evaluate how scientific research aids economic development and human progress in relation to, for example:
  - nuclear power generation
- Evaluate the impacts of scientific research, devices and applications and world health and human wellbeing.

### Working Scientifically

- Questioning and predicting
- Processing data and information
- Analysing data and information
- Problem solving
- Communicating

Our *ANSTO Year 12 Investigating Science Depth Study Guide* provides students and teachers with ideas and resources for depth study activities after their excursion.

## NESA requirements for Depth Studies

- A minimum of 30 hours of in-class time is allocated in both Year 11 and Year 12
- At least one depth study must be included in both Year 11 and Year 12
- The two Working Scientifically outcomes of Questioning and Predicting, and Communicating must be addressed in both Year 11 and Year 12
- A minimum of two additional Working Scientifically skills outcomes, and further development of at least one Knowledge and Understanding outcome, are to be addressed in all depth studies.

## Topic 1: Milestones in understanding nuclear science

### **Knowledge and understanding outcomes**

Module 6:

- Using examples, assess the impact that developments in scientific theories, laws and models have had on the development of new technologies, including but not limited to:
  - radioactivity and radioactive decay on the development of radiotherapy and nuclear bombs
- Using examples, assess the impact that developments in technologies have had on the accumulation of evidence for scientific theories, laws and models, including but not limited to:
  - technology to detect radioactivity and the development of atomic theory

### **Suggested activities**

- Create an annotated timeline of significant events, discoveries and developments in one of the following areas of nuclear science:
  - a) Understanding the mutagenic effect of radiation on living cells, and its applications in nuclear medicine, agriculture and radiation safety
  - b) Understanding fission and binding energy, and their applications in reactors and weapons
  - c) Understanding radioactive decay and half-life, and their applications in isotopic dating
- Compare and contrast historical methods of detecting radiation with more current technologies, including scintillation counters, dosimeters and thermoluminescent devices.
- Explain how technology used in one of the following “Big Science” projects is progressing our understanding of the following theories, laws and models:
  - a) The Large Hadron Collider and particle physics
  - b) The Laser Interferometer Gravitational-Wave Observatory (LIGO) and gravitational waves
  - c) The Square Kilometre Array and our fundamental scientific understanding of the universe
  - d) The ITER project and applications of fusion

### **Suggested resources**

ABC. (2018). “Irresistible sterile flies released to mate with female fruit flies in SA. Web article. <http://www.abc.net.au/news/2018-04-03/infertile-fruit-fly-drop-to-contain-outbreak/9612612>

ANSTO. (2018). Radioisotope posters. Poster. [www.ansto.gov.au/posters](http://www.ansto.gov.au/posters)

ANSTO. (2018). Isotopic dating. Website.

<http://www.ansto.gov.au/ResearchHub/OurResearch/environmentresearch/Capabilities/IsotopicDating/index.htm>

CERN. (2018). About CERN. Website. <https://home.cern/about>

ITER. (2018). ITER. Website. <https://www.iter.org/>

LIGO. (2018). Laser Interferometer Gravitational-Wave Observatory. Website. <https://www.ligo.caltech.edu/>

SKA Australia. (2018). The Square Kilometre Array. Website. <http://www.ska.gov.au>

United Nations Environment Programme. (2016). Radiation: Effects and sources. Fact sheet. [www.ansto.gov.au/factsheets](http://www.ansto.gov.au/factsheets)

ANSTO. (2014). Radiocarbon dating. Fact sheet. [www.ansto.gov.au/factsheets](http://www.ansto.gov.au/factsheets)

ANSTO. (2013). What is radiation. Brochure.

<http://www.ansto.gov.au/Resources/Publications/BooksandLeaflets/index.htm>

ANSTO. (2012). Nuclear Science Study Guide. Workbook. [www.ansto.gov.au/workbooks](http://www.ansto.gov.au/workbooks).

ANSTO. (2012). Nuclear medicine: Answering your questions. Brochure.  
<http://www.ansto.gov.au/Resources/Publications/BooksandLeaflets/index.htm>

## Topic 2: Nuclear science and public perception

### Knowledge and understanding outcomes

Module 8:

- Investigate case studies of past events to consider how they have affected the public image of science, including but not limited to:
  - meltdowns of nuclear reactors

### Suggested activities

- Australia is building a new nuclear research reactor and you are heading the communications team. Write a report detailing three ways you will provide information to the local community about this new facility. Consider how your strategy might reach people with different opinions about nuclear.
- List everyday sources of background radiation and compare the levels of background radiation that people are exposed to in different countries.
- You are a journalist working for the Sydney Morning Herald. Write a newspaper article to:
  - a) Summarise the events at the Fukushima Daiichi reactors following the earthquake and tsunami on 11 March 2011. Your editor wants to know what happened at the nuclear facility and how the local communities were affected in the first week after the accident.
  - b) Assess how the incident has affected public opinion of nuclear science in Japan and in other countries.
- Design and perform an experiment to demonstrate how time, distance and shielding can be used to minimise dose to radiation workers.
- Is a world without nuclear realistic? Research all the ways radiation is used in Australia and write a Powerpoint presentation to communicate your findings to members of an anti-nuclear organisation.
- Moata was one of Australia's first reactors and ran successfully for 34 years. It was shut down in 1995. Write the entry for a history textbook about the story of Moata.

### Suggested resources

- ANSTO. (2018). Nuclear science inquiry skills. Videoconference. [www.ansto.gov.au/elearning](http://www.ansto.gov.au/elearning).
- ANSTO. (2018). 60 years of ANSTO in photos. Website. <http://www.ansto.gov.au/AboutANSTO/HistoryatANSTO/photogallery/index.htm>
- Department of Industry, Innovation and Science. (2018). National Radioactive Waste Management Facility. Website. <http://www.radioactivewaste.gov.au/>
- ANSTO. (2017). Our community. Website. <http://www.ansto.gov.au/AboutANSTO/Ourcommunity/index.htm>
- Department of Industry, Innovation and Science. (2017). Beneficial uses of radiation. Website. <https://industry.gov.au/resource/RadioactiveWaste/RadiationandRadioactiveWaste/Pages/Beneficialusesofradiation.aspx>
- Suzuki, T. (2017). Six years after Fukushima, much of Japan has lost faith in nuclear power. The Conversation. <http://theconversation.com/six-years-after-fukushima-much-of-japan-has-lost-faith-in-nuclear-power-73042>
- World Nuclear Association. (2017). Fukushima Accident. Website. <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-accident.aspx>
- ANSTO. (2016). What is radiation? Video. [www.ansto.gov.au/educationvideos](http://www.ansto.gov.au/educationvideos)
- Nuclear Fuel Cycle Royal Commission. (2016). 9 May 2016 – Nuclear fuel cycle Royal Commission – Report delivered. Media Release. <http://nuclearrc.sa.gov.au/media-centre/nuclear-fuel-cycle-royal-commission-report-delivered/>

- United Nations Environment Programme. (2016). Radiation: Effects and sources. Fact sheet. [www.ansto.gov.au/factsheets](http://www.ansto.gov.au/factsheets)
- ANSTO. (2013). What is radiation? Brochure. [www.ansto.gov.au/resources/publications/booksandleaflets](http://www.ansto.gov.au/resources/publications/booksandleaflets)
- McAneney, J., Bird, D., Haynes, K. and van den Honert, R. (2013). Why don't Australians see nuclear as a climate change solution? The Conversation. <https://theconversation.com/why-dont-australians-see-nuclear-as-a-climate-change-solution-19099>
- ANSTO (2012) Natural background radiation <http://www.ansto.gov.au/NuclearFacts/AboutNuclearScience/NaturalBackgroundRadiation/index.htm>
- ANSTO. (2012). Radiation: Moata research reactor. <http://www.ansto.gov.au/AboutANSTO/HistoryatANSTO/Decommissioningearlierreactors/Moata/index.htm>.

## Topic 3: Nuclear science, regulation and ethics

### Knowledge and understanding outcomes

Module 8:

- Investigate and assess ethical issues surrounding current scientific research in, for example:
  - use of radiation
- Investigate the need for the regulation of scientific research in, for example:
  - products and processes of the nuclear industry

### Suggested activities

- We are exposed to natural and manmade sources of radiation all the time, so we need to know about the potential health effects. Research experiments or historical events that have contributed to our understanding of radiation exposure and present your findings on a timeline.
- Create a Powerpoint presentation showing all the products that are sterilised using radiation. Consider alternate methods for sterilising each of these products and decide whether they are more or less efficient than radiation.
- The Non-Proliferation Treaty is an agreement between countries not to manufacture nuclear weapons. The treaty also encourages the sharing of nuclear knowledge between all the countries who signed it. Write an essay describing the Nuclear Fuel Cycle and consider reason why it is beneficial for countries to share their knowledge and expertise.
- Everybody who works at a nuclear facility is monitored for the levels of radiation they are exposed to. Research three pieces of equipment used to monitor radiation levels – electronic personal dosimeter, thermoluminescent device, scintillation counter – and produce a manual to explain, to employees, how they work.
- If we build and run nuclear research reactors today, we must store our nuclear waste responsibly because we have a duty of care to future generations. Research the different nuclear medicines that are produced in nuclear research reactors and how the waste from their production is stored. Do the benefits of nuclear medicine outweigh the issues of nuclear waste?
- Ionising smoke alarms are fitted with a radioactive source, Americium-241. Do you think that most people are aware of this radioactive source in their house, and would they get rid of smoke alarms if they knew? Create a poster showing how smoke alarms work and explain why it is safe to have one in the home.
- What is the ethical responsibility of the media when reporting on nuclear accidents? You are the news editor at the Sydney Morning Herald. Write an email to your staff explaining the importance of good scientific journalism and your wish to avoid hysteria among your readers. Include links to articles that have reported on nuclear accidents in a measured, unbiased manner.

### Suggested resources

- ANSTO. (2018). Day in the life of Australian nuclear medicine. Video. [www.ansto.gov.au/educationvideos](http://www.ansto.gov.au/educationvideos)
- ANSTO. (2018). Nuclear science inquiry skills. Videoconference. [www.ansto.gov.au/elearning](http://www.ansto.gov.au/elearning).
- Department of Industry, Innovation and Science. (2018). National Radioactive Waste Management Facility. Website. <http://www.radioactivewaste.gov.au/>
- ANSTO. (2017). Four million nuclear medicine doses produced. Video. [www.ansto.gov.au/educationvideos](http://www.ansto.gov.au/educationvideos)
- ANSTO. (2017). The scientists behind life-saving cancer treatments. Video. [www.ansto.gov.au/educationvideos](http://www.ansto.gov.au/educationvideos)
- ANSTO. (2017). The nuclear fuel cycle. Website. <http://www.ansto.gov.au/NuclearFacts/ManagingRadioActiveWaste/Theuclearfuelcycle/>

- Department of Industry, Innovation and Science. (2017). Beneficial uses of radiation. Website. <https://industry.gov.au/resource/RadioactiveWaste/RadiationandRadioactiveWaste/Pages/Beneficialusesofradiation.aspx>
- IAEA. (2017). Treaty on the non-proliferation of nuclear weapons. Website. <https://www.iaea.org/publications/documents/treaties/npt>
- World Nuclear Association. (2017). Fukushima Accident. Website. <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-accident.aspx>
- ANSTO. (2016). What is radiation? Video. [www.ansto.gov.au/educationvideos](http://www.ansto.gov.au/educationvideos)
- United Nations Environment Programme. (2016). Radiation: Effects and sources. Fact sheet. [www.ansto.gov.au/factsheets](http://www.ansto.gov.au/factsheets)
- United Nations Office for Disarmament Affairs. (2015). Treaty on the non-proliferation of nuclear weapons. Website. <https://www.un.org/disarmament/wmd/nuclear/npt/>
- National Fire Protection Association. (2014). Ionising smoke alarms. Website. <https://www.nfpa.org/-/media/Files/Public-Education/By-topic/Smoke-alarms/Ionization-smoke-alarm-chart.ashx?la=en>
- ANSTO. (2013). What is radiation? Brochure. [www.ansto.gov.au/resources/publications/booksandleaflets](http://www.ansto.gov.au/resources/publications/booksandleaflets)

## Topic 4: Nuclear science – benefitting human-kind

### *Knowledge and understanding outcomes*

Module 8:

- Evaluate how scientific research aids economic development and human progress in relation to, for example
  - nuclear power generation
- Evaluate the impacts of scientific research, devices and applications on world health and human wellbeing.

### Suggested activities

- You work for a gamma irradiation company that specialises in the mutation of genes in crops to improve food production. Create a Powerpoint presentation explaining the role of radiation in GM crops and highlight some of the benefits of producing enhanced foods in low-economic countries. Include a slide in your presentation that lists other uses of gamma irradiation so that your work is placed in a broader context.
- Radioisotopes are used to map groundwater so that wells can be dug. Write a feature article for National Geographic, using research carried out in Mozambique as a case study.
- Compare the reliability of different carbon-zero energy resources, including nuclear and solar. Present your findings in the form of a poster. Do you think that a country can run on power from a single resource, or would a combination of resources be better?
- Gamma-emitting radioisotopes are used in the diagnosis of cancer, while beta-emitting radioisotopes are used in the treatment of cancer.
  - a) Compare the properties of beta and gamma radiation to explain why they are used for different medical processes.
  - b) Consider why alpha radiation is not used in the diagnosis or treatment of cancer.
- Gamma irradiation is used to sterilise body parts for transplantation. Create a hospital pamphlet:
  - a) Detailing which body parts can be sterilised with radiation.
  - b) Explaining the benefits to the patient of sterilising body parts prior to transplantation.
- Fine particle pollution is a problem in urban areas. The local council wants to inform their residents and they have asked you to produce a brochure explaining:
  - a) What fine particle pollution is and where it comes from.
  - b) The health effects of fine particle pollution.
  - c) Research carried out using particle accelerators that tells us more about fine particle pollution.

### Suggested resources

ANSTO. (2018). Food and Agriculture. Website.

<http://www.ansto.gov.au/NuclearFacts/BenefitsofNuclearScience/FoodandAgriculture/index.htm>

ANSTO. (2018). Human Health. Website.

<http://www.ansto.gov.au/NuclearFacts/BenefitsofNuclearScience/HumanHealth/index.htm>

ANSTO. (2018). Irradiation Services. Website.

<http://www.ansto.gov.au/NuclearFacts/BenefitsofNuclearScience/IrradiationServices/index.htm>

ANSTO. (2018). Multipurpose research reactor providing radioactive phosphorous for implantable medical device to treat pancreatic cancer in global clinical trial. News article.

<http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS176965>

ANSTO (2018). Nuclear Energy. Website.

<http://www.ansto.gov.au/NuclearFacts/BenefitsofNuclearScience/NuclearEnergy/index.htm>

ANSTO. (2018). Nuclear Medicine. Website. <http://www.ansto.gov.au/AboutANSTO/WhatANSTOdoes/Nuclearmedicine/index.htm>

ANSTO. (2018). Nuclear Power Reactors. Website. <http://www.ansto.gov.au/NuclearFacts/AboutNuclearScience/ReactorsandAccelerators/NuclearPowerReactors/index.htm>

ANSTO. (2018). Supply of nuclear medicine lutetium-177 for advanced prostate cancer highlighted in the news. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS179627>

International Atomic Energy Agency. (2018). Energy. Website. <https://www.iaea.org/topics/energy>

International Atomic Energy Agency. (2018). Food irradiation and the changing climate. News article. <https://www.iaea.org/newscenter/multimedia/videos/food-irradiation-and-the-changing-climate>

International Atomic Energy Agency. (2018). Health. Website. <https://www.iaea.org/topics/health>

International Atomic Energy Agency. (2018). NEW CRP: Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change. News article. <https://www.iaea.org/newscenter/news/new-crp-disease-resistance-in-rice-and-wheat-for-better-adaptation-to-climate-change-d23032>

International Atomic Energy Agency. (2018). Water. Website. <https://www.iaea.org/topics/water>

National Foundation for Infectious Diseases. (2018). Food Irradiation: A Public Health Opportunity. Website. <http://www.nfid.org/links/irradiation-foodborne-disease/steele.html>

O'Hare, R. (2018). Air pollution in England could cost as much as £5.3 billion by 2035. News article (Imperial College London). <https://www.imperial.ac.uk/news/186406/air-pollution-england-could-cost-much/>

University of Minnesota Food Policy Research Center. (2018). Food irradiation and public health. Website. <https://www.foodpolicy.umn.edu/policy-summaries-and-analyses/food-irradiation-and-public-health>

The Accelerators for Society Project. (2018). Accelerators for Society – Industrial Applications. Website. <http://www.accelerators-for-society.org/industry/index.php?id=8>

Food Standards Australia and New Zealand (2017). Food irradiation. Website. <http://www.foodstandards.gov.au/consumer/foodtech/irradiation/Pages/default.aspx>

ANSTO. (2016). Using nuclear techniques to help sustain Australia's finite groundwater resources. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS101040>

ANSTO. (2014). ANSTO's groundwater research in the Pilbara WA. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS047079>

ANSTO. (2014). Mapping the groundwater resources of Mozambique. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS045189>

ANSTO (2014). Revealing the sources of Sydney's air pollution. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS049674>

ANSTO. (2013). Air pollution chasers: Nuclear techniques to track air pollution. News article. <http://www.ansto.gov.au/AboutANSTO/MediaCentre/News/ACS044787>

Cohen, D. D., Stelcer E., Hawas, O. and Garton, D. (2004). IBA methods for characterisation of fine particulate atmospheric pollution: a local, regional and global research problem". Nuclear Instruments and Methods in Physics Research B. 219-220:145-152 ([http://www.ansto.gov.au/\\_data/assets/pdf\\_file/0016/40426/CohenPDF1.pdf](http://www.ansto.gov.au/_data/assets/pdf_file/0016/40426/CohenPDF1.pdf))