Australian Government

Nuclear-based science benefiting all Australians

Welcome to ANSTO

(Australian Nuclear Science and Technology Organisation)

An outcomes based resource manual for NSW HSC Chemistry students

9.2 Production of Materials

5. Nuclear chemistry provides a range of materials

9.4 Chemical Monitoring and Management

The aim of this workbook is to provide you with information to assist you in your study areas of Nuclear Chemistry and Chemical Monitoring and Management as outlined below. This workbook is a guide only – your teacher is the final authority

Stage 6 Syllabus Chemistry
9.2 Production of Materials
5. Nuclear chemistry provides a range of materials
9.4 Chemical Monitoring and Management

This manual aims to address the following outcomes

	HSC Course Objectives	Outcomes
PFA	History of chemistry Nature and practice of chemistry Applications and uses of chemistry Implications for society and the environment Current issues, research and developments in chemistry	9.2 H1, H2, H3, H4, H5 9.4 H1, H2, H3
Knowledge & Understanding		9.2 H6, H7, H8, H10 9.4 H8, H10
Skills		9.2 H11, H12, H13, H14, H15 9.3 H11, H12, H13, H14, H15

9.2 Production of Materials

5. Nuclear chemistry provides a range of materials

Students learn to:

- distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable
- describe how transuranic elements are produced
- describe how commercial radioisotopes are produced
- identify instruments and processes that can be used to detect radiation

- identify one use of a named radioisotope:
  - o in industry o
    in medicine

- describe the way in which the above named radioisotopes are used and explain their use in terms of their chemical properties

Students:

- process information from secondary sources to describe recent discoveries of elements
- use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine

9.4 Chemical Monitoring and Management

1. Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions

Students learn to:

- outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses
- identify the need for collaboration between chemists as they collect and analyse data
- describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring

Students:

- gather, process and present information from secondary sources about the work of practising scientists identifying:
  - o the variety of chemical occupations
  - o a specific chemical occupation for a more detailed study

On your visit to ANSTO our Education Officers will explain and demonstrate various aspects of nuclear chemistry.

You will visit:

- The Education Centre for an introduction and overview. **Please be sure to collect the following brochures**
  - Glossary of nuclear terms
  - Medical and Industrial Radioisotopes
  - Ionising Radiation
  - National Medical Cyclotron

- OPAL (Open Pool Australian Lightwater reactor)
  - you will be shown the reactor and the neutron beam guide hall.

- ARI (ANSTO Radiopharmaceuticals and Industrials)
  - experience a hot-cell where radioisotopes are removed for specific medical and industrial purposes

- other scientific sites if time permits

Site Visit 1: Education Centre - introduction and overview

Students:

- process information from secondary sources to describe recent discoveries of elements

Q1. Identify an element discovered in the last 200 years

Q2. Identify two elements discovered in the last 50 years

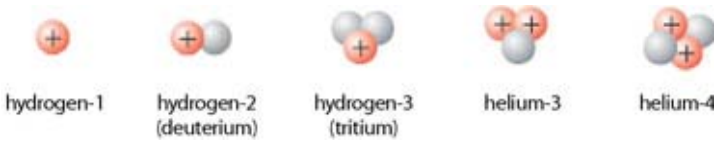
Q3. From the periodic table, account for where the most recent discoveries occurred

Students learn to:

- Distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable.

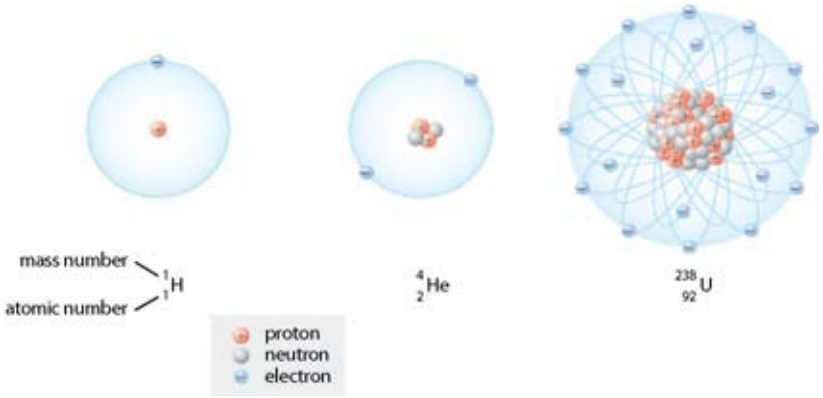
(Also refer to brochures: Glossary of Nuclear Terms; Ionising Radiation)

The nuclei for the five smallest isotopes and their chemical symbols are shown in the diagram below. The nucleus of nearly all atoms contains protons and neutrons. The hydrogen atom (as shown) is the only atom that does not contain neutrons. The number of protons is the atomic number (Z), the number of protons plus neutrons is the mass number (A).



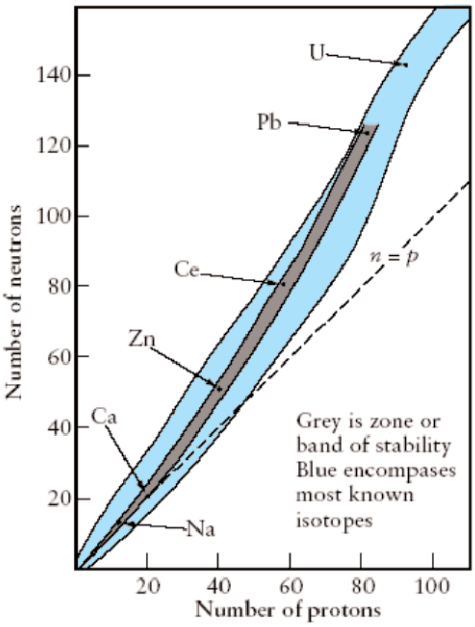
Q4. Describe what an isotope is

Look at the following diagram



Q5. Using the diagram and the information above explain the symbol $^{A}_{Z}X$

Q6. Clarify the terms stable and unstable isotopes



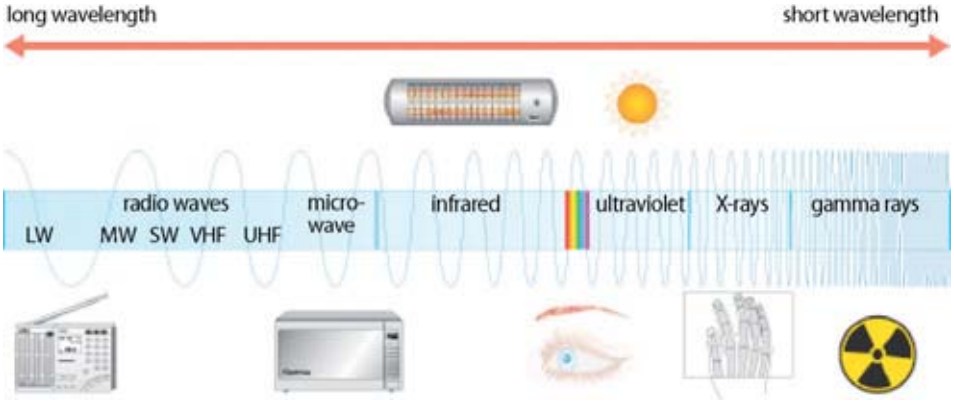
This is a graph of number of neutrons versus number of protons for all known isotopes (blue area); the grey shaded area is the zone of stability. (FIG. 3.1 Conquering Chemistry p69)

From the graph you are able to predict whether a given isotope is stable or not.

Q7. Identify three stable isotopes

Q8. Identify three radioisotopes (unstable isotopes)

Q9. Carbon - 12 is a stable isotope but Carbon -14 is radioactive. State reason for this



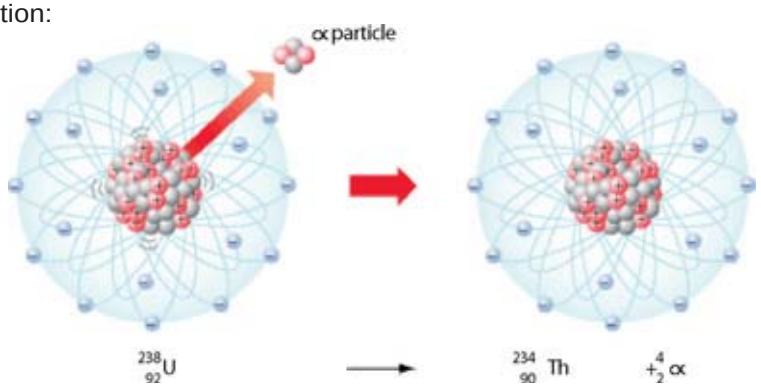
The electromagnetic spectrum at left shows that radiation can be explained as packets of light (photons) of different energy (the type of radiation depends on the amount of energy it has).

Q10. Define the term “nuclear radiation”

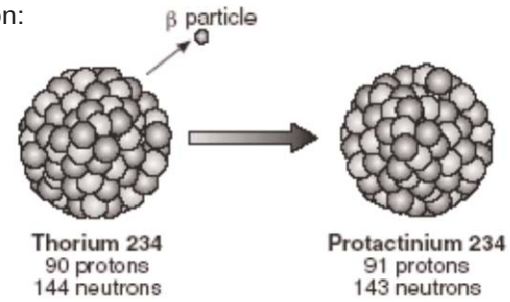
In 1896 French scientist Henri Becquerel discovered a new kind of invisible radiation that seemed to be emitted from a uranium-rich rock. This radiation could not be stopped, increased or decreased. This was nuclear radiation and it was something completely new to science. Marie Curie, working in Paris, coined the term 'radioactivity' to describe this new property, and discovered three new radioactive elements. Further studies by New Zealander Ernest Rutherford showed that this new radiation was actually three different types. He called these alpha (α), beta (β) and gamma (γ) radiation. Each of these types of radiation has its own characteristic properties. Different radioactive substances emit different combinations of these radiation.

Q11. Describe the nature of alpha (α), beta (β) and gamma (γ) radiation. Use examples to illustrate your answer.

Alpha radiation:



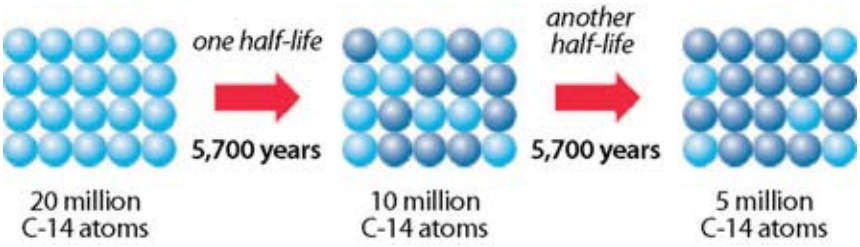
Beta radiation:



Gamma Radiation:

Q12. Compare Strontium-90 (Sr^{90}) to other radioisotopes. Why is it different?

Examine the following diagram:

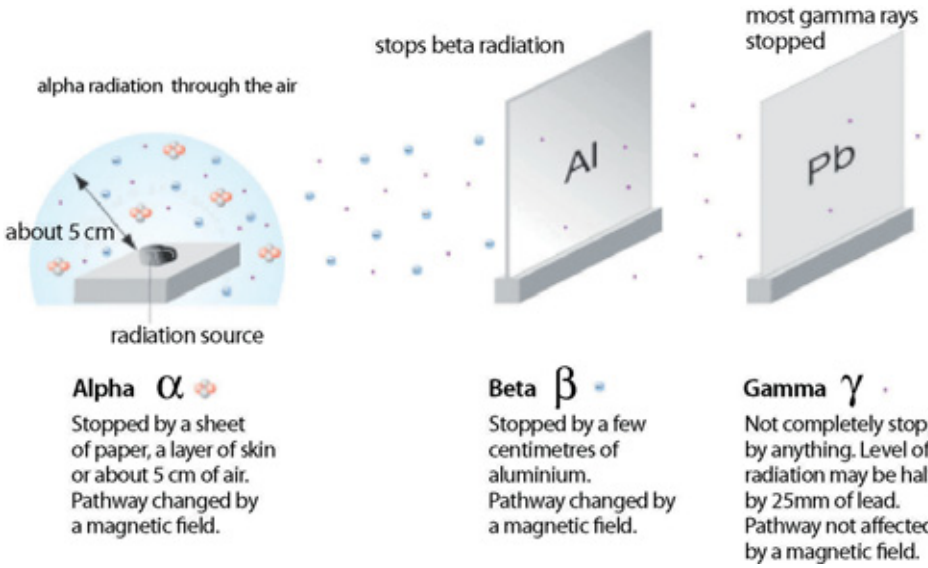


Q13. From this diagram, interpret the term "half life"

Q14. Account for the relevance of C-14's half life in the carbon dating technique

Q15. What is the unit used for measuring radiation?

Q16. Use the diagram below to describe the penetration power of the different types of radiation



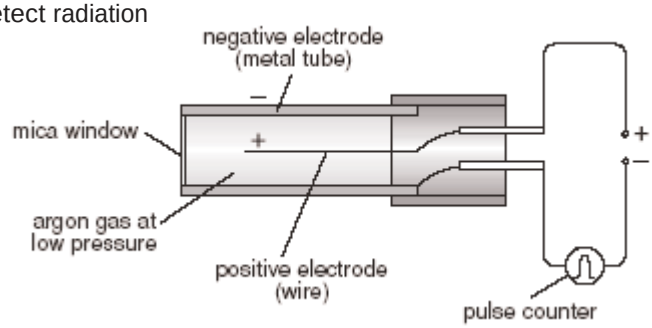
Q17. In summary, complete the following table.

Radiation	Symbol	Type	Example
Alpha		$^{4}_{2}He$	
	β		
Gamma			$^{60}_{27}Co \quad ^{60}_{28}Ni + \beta^{-} + \gamma$

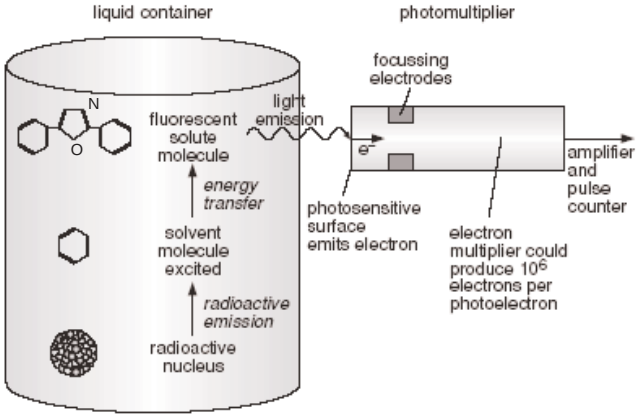
Students learn to:

- Identify instruments and processes that can be used to detect radiation

Q18. Outline the principles behind the detection system in a Geiger-Muller counter



Q19. Outline the principles behind the detection system in a scintillation counter



Q20. Describe how a cloud chamber is used to detect radiation

Site visit 2: OPAL

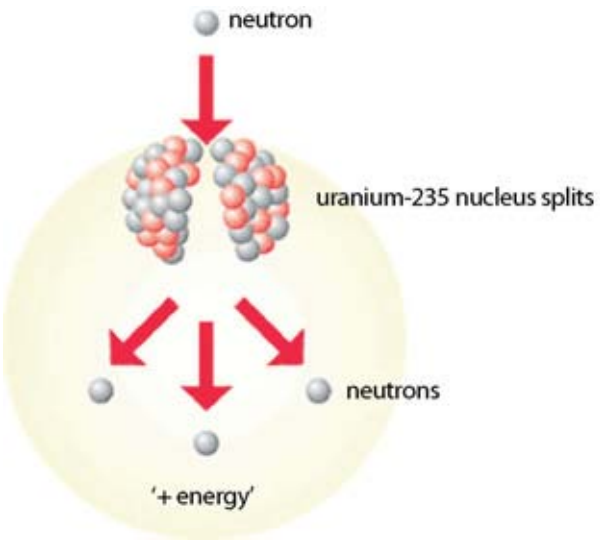
Q21. Nuclear reactors are used for a number of commercial purposes. These are:

1.

2.

3.

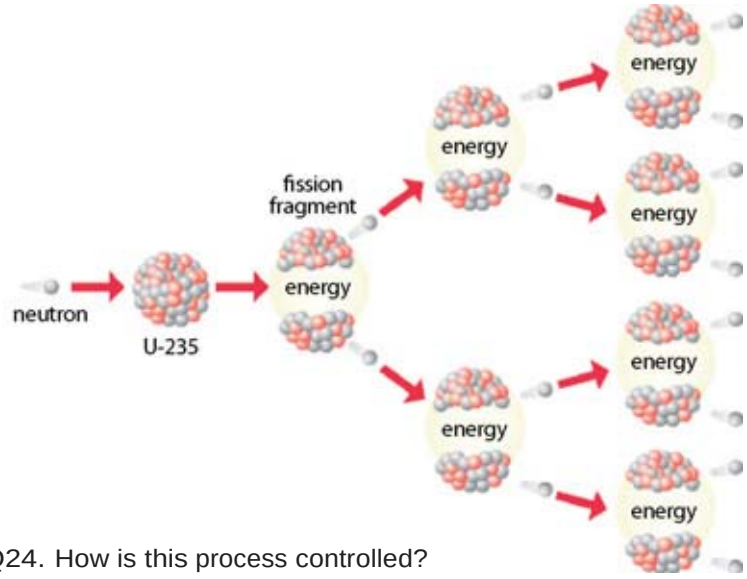
Below is a diagram showing nuclear fission



Q22. Explain the nuclear fission process

Q23. What is a fissionable material?

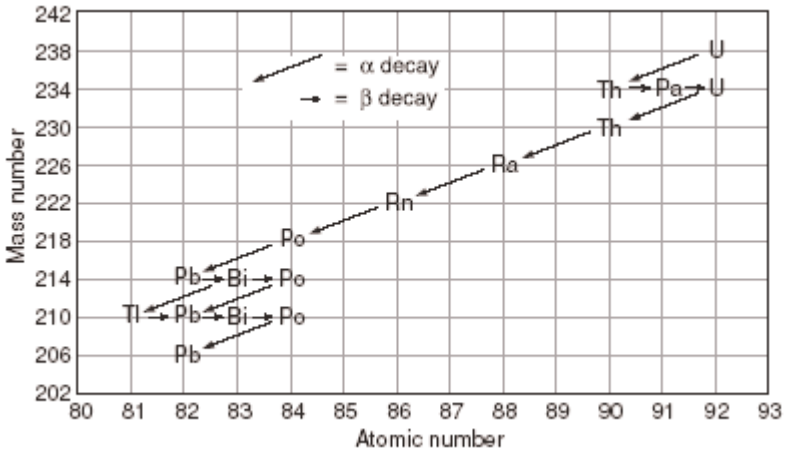
In a chain reaction, neutrons released from the splitting of one atom cause fission in additional atoms. These atoms in turn release still more neutrons, leading to a growing chain reaction as shown below.



Q24. How is this process controlled?

Q25. Write a nuclear equation to display the fission of a radioisotope (hint: 235U is fissionable)

Below is a flow diagram which traces the sequence of decay products released during the decay of uranium.



Q26. What is the overall change? (write it as an equation)

Students learn to:

- Describe how transuranic elements are produced

Q27. What is a transuranic element?

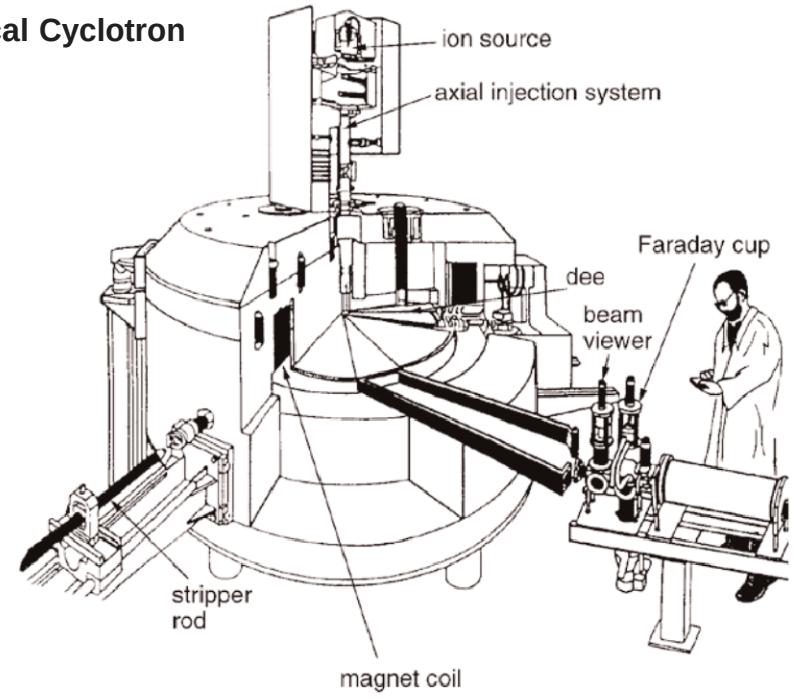
Q28. Name three transuranic elements

Q29. Describe how transuranic isotopes are produced in nuclear research reactors

Q30. What are the products that OPAL manufactures?

(also refer to brochure: ANSTO medical and industrial Radioisotopes)

ANSTO National Medical Cyclotron



Q31. Describe the process that the cyclotron uses to produce radioactive isotopes.

Use an example in your answer
(also use brochure: ANSTO National Medical Cyclotron)

Q32. Contrast a nuclear reactor to a cyclotron?

Site visit 3: ANSTO Radiopharmaceuticals and Industrials - ARI

ARI provides a wide range of nuclear based products and services

Left: The High Activity handling cell

Students learn to:

- Describe how commercial radioisotopes are produced

Q33. Identify a commercial radioisotope

Q34. Describe how a commercial radioisotope is produced

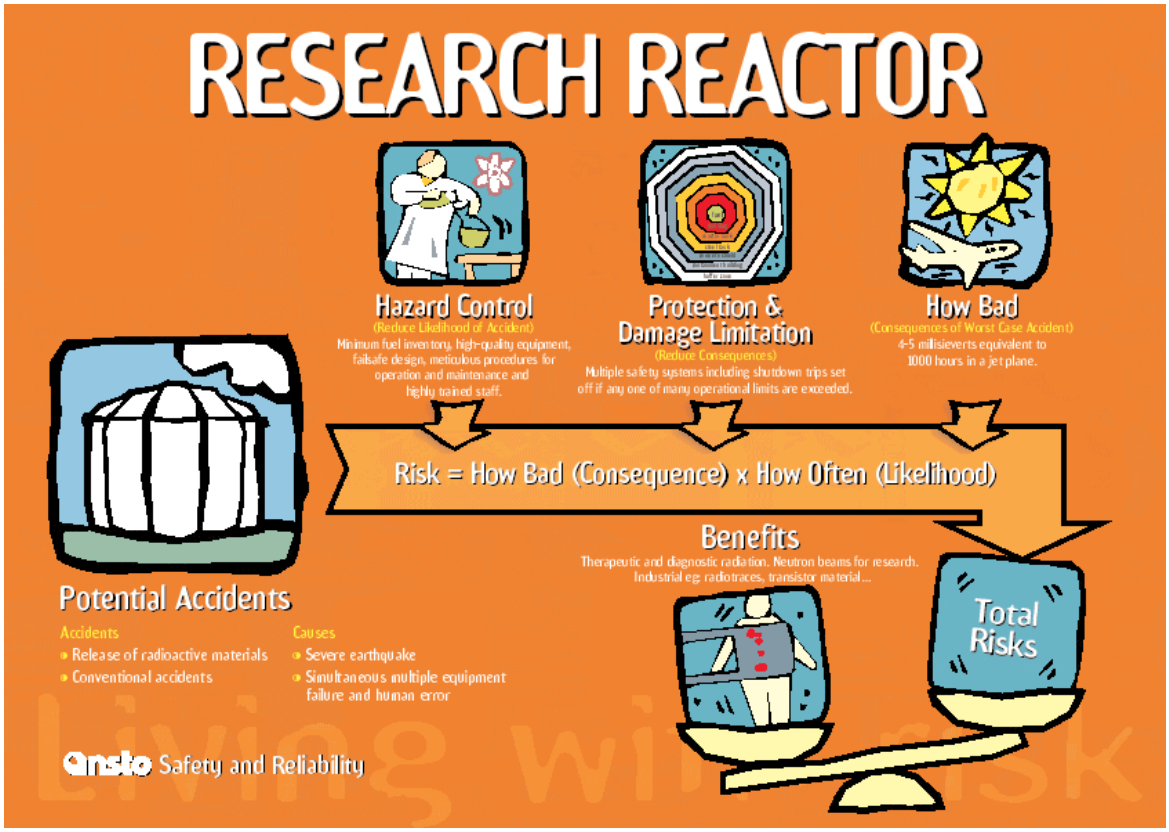
Students learn to:

- Identify one use of a named radioisotope
  - o in industry
  - o in medicine

Q35. Case Studies

Complete the following table:

radioisotope used in industry eg: Iridium-192	radioisotope used in medicine Eg: Molybdenum-99 and Technetium–99m
Use:	Use:
Benefit:	Benefit:
Safety precautions required:	Safety precautions required:



Students learn to:

- use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine

Choose a radioisotope that you have studied.

Q36. Describe the problems associated with the use of radioisotopes in society

Q37. Justify the benefits of using radioisotopes in either industry or medicine

9.4 Chemical Monitoring and Management

1. Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions

During your tour of ANSTO you will have observed the nature, practice, applications and uses of nuclear chemistry for society and the environment. You will have experienced first hand how nuclear technologies are applied. The information you have gathered will help you complete the following dot points:

Students learn to:

- outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses

Q38. Outline the role of a chemist employed at ANSTO, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses

Students learn to:

- identify the need for collaboration between chemists as they collect and analyse data

Q39. Identify the need for collaboration between chemists as they collect and analyse data.

Students learn to:

- gather, process and present information from secondary sources about the work of practising scientists identifying:
  - the variety of chemical occupations
  - a specific chemical occupation for a more detailed study

Q40. Identify three different chemical occupations at ANSTO

Q41. Describe the role of one of the above occupations

Extension questions

Q42. Using examples, describe processes by which an unstable isotope undergoes radioactive decay

7 marks

Q43. Describe in terms of the chemistry involved how commercial radioisotopes are produced and how transuranic elements are produced

7 marks

Q44. Outline the structure and principle of one instrument used to measure radiation

6 marks

Q45. Assess the benefits and disadvantages of using radioisotopes in society

8 marks

Q46. Identify a practising Australian scientist, the area in which he/she is currently working and describe the research work they are conducting.

8 marks

Q47. Describe the physical and chemical processes that need to be monitored at a nuclear reactor site.

4 marks

Notes

Glossary of Verbs

- Account: Account for: state reasons for, report on. Give an account of: narrate a series of events or transactions
- Analyse: Identify components and the relationship between them; draw out and relate implications
- Apply: Use, utilise, employ in a particular situation
- Appreciate: Make a judgement about the value of
- Assess: Make a judgment of value, quality, outcomes, results or size
- Calculate: Ascertain/determine from given facts, figures or information
- Clarify: Make clear or plain
- Classify: Arrange or include in classes/categories
- Compare: Show how things are similar or different
- Construct: Make; build; put together items or arguments
- Contrast: Show how things are different or opposite
- Critically (analyse/ evaluate): Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to (analysis/evaluation)
- Deduce: Draw conclusions
- Define: State meaning and identify essential qualities
- Demonstrate: Show by example
- Describe: Provide characteristics and features
- Discuss: Identify issues and provide points for and/or against
- Distinguish: Recognise or note/indicate as being distinct or different from; to note differences between
- Evaluate: Make a judgement based on criteria; determine the value of
- Examine: Inquire into
- Explain: Relate cause and effect; make the relationships between things evident; provide why and/or how
- Extract: Choose relevant and/or appropriate details
- Extrapolate: Infer from what is known
- Identify: Recognise and name
- Interpret: Draw meaning from
- Investigate: Plan, inquire into and draw conclusions about
- Justify: Support an argument or conclusion
- Outline: Sketch in general terms; indicate the main features of
- Predict: Suggest what may happen based on available information
- Propose: Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
- Recall: Present remembered ideas, facts or experiences
- Recommend: Provide reasons in favour
- Recount: Retell a series of events
- Summarise: Express, concisely, the relevant details
- Synthesise: Putting together various elements to make a whole

Credits

Written by Leda McFadzean, BSc, Dip Ed
Coordinated by the Department of Education and Training and ANSTO

USEFUL REFERENCE MATERIAL

Board of Studies NSW Chemistry Syllabus amended version 2002
Hefferenan, D. Spotlight HSC Chemistry, Science Press, 2005
Smith, R. Conquering Chemistry HSC Course 4th Edition McGraw Hill Australian, 2005
Irwin, Farrelly, Vitlin & Garnett, Chemistry Context 2, Longman Sciences 2002

WEB REFERENCES:

ANSTO web site www.ansto.gov.au
Charles Sturt University, HSC Online web site, Chemistry http://hsc.csu.edu.au/chemistry/