Module 8: From the Universe to the Atom

Origins of the Elements

Inquiry question: What evidence is there for the origins of the elements?

Students:

- investigate the processes that led to the transformation of radiation into matter that followed the 'Big Bang'
- investigate the evidence that led to the discovery of the expansion of the Universe by Hubble
- analyse and apply Einstein's description of the equivalence of energy and mass and relate this to the nuclear reactions that occur in stars
- account for the production of emission and absorption spectra and compare these with a continuous black body spectrum
- investigate the key features of stellar spectra and describe how these are used to classify stars
- investigate the Hertzsprung-Russell diagram and how it can be used to determine the following about a star:
  - characteristics and evolutionary stage
  - surface temperature
  - colour
  - luminosity
- investigate the types of nucleosynthesis reactions involved in Main Sequence and Post-Main Sequence stars, including but not limited to:
  - proton–proton chain
  - CNO (carbon-nitrogen-oxygen) cycle

Structure of the Atom

Inquiry question: How is it known that atoms are made up of protons, neutrons and electrons?

Students:

- investigate, assess and model the experimental evidence supporting the existence and properties of the electron, including:
  - early experiments examining the nature of cathode rays
  - Thomson's charge-to-mass experiment
  - Millikan's oil drop experiment

- investigate, assess and model the experimental evidence supporting the nuclear model of the atom, including:

  – the Geiger-Marsden experiment

  – Rutherford's atomic model

  – Chadwick's discovery of the neutron

Quantum Mechanical Nature of the Atom

Inquiry question: How is it known that classical physics cannot explain the properties of the atom?

Students:

- assess the limitations of the Rutherford and Bohr atomic models
- investigate the line emission spectra to examine the Balmer series in hydrogen (ACSPH138)
- relate qualitatively and quantitatively the quantised energy levels of the hydrogen atom and the law of conservation of energy to the line emission spectrum of hydrogen using:

  – $E = hf$

  – $E = \frac{hc}{\lambda}$

  – $\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$

- investigate de Broglie's matter waves, and the experimental evidence that developed the following formula:

  – $\lambda = \frac{h}{mv}$

- analyse the contribution of Schrödinger to the current model of the atom

Properties of the Nucleus

Inquiry question: How can the energy of the atomic nucleus be harnessed?

Students:

- analyse the spontaneous decay of unstable nuclei, and the properties of the alpha, beta and gamma radiation emitted
- examine the model of half-life in radioactive decay and make quantitative predictions about the activity or amount of a radioactive sample using the following relationships:

  – $N_{\mathrm{t}} = N_{\mathrm{o}} e^{-\lambda t}$

  – $\lambda = \frac{ln2}{t_{1/2}}$

where N_t = number of particles at time t, N_0 = number of particles present at $t = 0$, λ = decay constant, $t_{1/2}$ = time for half the radioactive amount to decay

- model and explain the process of nuclear fission, including the concepts of controlled and uncontrolled chain reactions, and account for the release of energy in the process (ACSPH033, ACSPH034)
- analyse relationships that represent conservation of mass-energy in spontaneous and artificial nuclear transmutations, including alpha decay, beta decay, nuclear fission and nuclear fusion
- account for the release of energy in the process of nuclear fusion
- predict quantitatively the energy released in nuclear decays or transmutations, including nuclear fission and nuclear fusion, by applying:
  - the law of conservation of energy
  - mass defect
  - binding energy
  - Einstein's mass–energy equivalence relationship $E = mc^2$

Deep inside the Atom

Inquiry question: How is it known that human understanding of matter is still incomplete?

Students:

- analyse the evidence that suggests:
  - that protons and neutrons are not fundamental particles
  - the existence of subatomic particles other than protons, neutrons and electrons
- investigate the Standard Model of matter, including:
  - quarks, and the quark composition hadrons
  - leptons
  - fundamental forces
- investigate the operation and role of particle accelerators in obtaining evidence that tests and/or validates aspects of theories, including the Standard Model of matter