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Nuclear Equation Role-play

Background:

Knowledge of what happens when a radioactive nucleus undergoes decay is the key to understanding how to balance nuclear equations. This activity uses role-play to build on and develop an understanding of the atom and radioactive decay, as well as explaining the concept of nuclear equations. The resource itself contains two tasks – the role-play activity and a card matching activity which includes extension tasks. The card matching activity assesses students ability to construct nuclear equations. They can be completed individually, in pairs or larger groups; as a race or completed within a set time.

Curriculum Link:

- ***HS-PS1-8.*** Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Learning Objectives:

1. Describe the features of alpha, beta and gamma emission.
2. Write equations for the decay of elements by alpha and beta emission.

Prior Knowledge:

The following concepts must have been covered before undertaking this activity:

- The structure of the atom
- Charges of sub-atomic particles
- Using the periodic table to find the atomic number and mass numbers of an element
- Calculating the number of protons, electrons and neutrons for any given element.

Pre-lab Questions:

1. How do we describe the nucleus of an element using chemical shorthand?
   $^{4}_{2}He$

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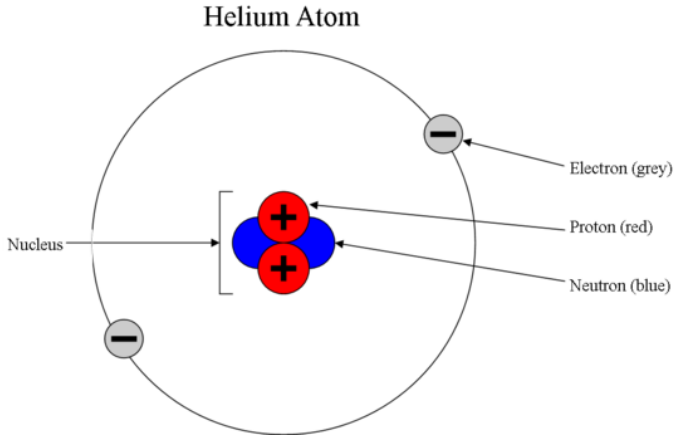
2. Draw the structure of a helium atom.



3. Explain why helium is considered:
   a. Inert
      Helium has a complete valence shell (2 electrons) making it unreactive.

   b. An atom rather than an ion.
      As helium has a full shell, it can neither give nor receive electrons from other atoms.

4. Write down the chemical notation for polonium-215
   $^{215}_{84}Po$

5. What happens when a radioactive nucleus emits an alpha particle?
   An alpha particle is made up of two protons and two neutrons (a helium nucleus). This leads to the decay of the nucleus into a different element.

6. List two uses and two dangers of alpha emission
   Dangers:
   Damages DNA
   Can causing burning to flesh

   Uses:
   Cancer treatment
   Smoke detectors
   Pacemaker batteries
   Heating devices
   Coastguard buoys
   Powering seismic and oceanic devices
   Powering satellites

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7. Give the shorthand notation that represents a beta particle.
   ${}^{0}_{-1}e$
8. What happens when a radioactive nucleus emits a beta particle?
   A beta particle forms when a neutron changes into a proton and a high-energy electron. The proton remains in the nucleus but the electron is ejected/emitted from the atom as a beta particle.

9. Outline two uses and dangers of beta decay.
   Beta radiation can penetrate the skin and damage cells
   Causes skin burns

   Uses
   Quality control to test the thickness of objects
   Medicine
   Tracers

10. How would gamma radiation be represented in shorthand form?
    ${}^{0}_{0}\gamma$

11. What happens when a radioactive nucleus emits gamma radiation?
    Gamma rays do not alter the number of protons or neutrons in the nucleus but can move the nucleus from a higher to a lower energy state (unstable to stable).

What you'll need:

- Designate an area of the classroom to be the nucleus
- A4 size colored sheets/cards labeled as follows:
  - 4 yellow cards labeled 'neutron' or 'n'
  - 1 yellow card labeled '128 neutrons' or '128n'
  - 3 green cards labeled 'proton' or 'p'
  - 2 green cards labeled '82 proton' or '82p'
  - 2 red cards labeled 'electron' or 'e'
- 3 large A4-size envelopes (two of these are empty, while the third contains a single proton and single electron card)
- Periodic tables (either laminated cards or from textbooks)
- alpha/beta decay nuclear equation sheets (one per student)
- thorium-232 cards (an extension task if required)

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What to Do:

Answers to the pre-lab questions will be addressed as the class progresses through the role-play activities.

Role play Activity 1: Examining the radioactive decay of Polonium-215 nucleus by alpha particle emission.

1. Select 8 students to model a helium atom using 2 yellow 'neutron' cards, 2 green 'proton' cards and 2 red 'electron' cards. The proton and electron cards should be held by individual students, while the neutron cards jointly by two students. Explain that the reason for this will become clear when beta decay is considered. (i.e. Pre-lab questions 1-3)
2. Next, discuss with the class how to model the polonium-215 nucleus which contains 84 protons and 131 neutrons. Select 10 students to model polonium-215. Again, it is important that the 'single' neutron 'cards' are held jointly by two students. (i.e. Pre-lab question 4)
3. Answer pre-lab question 5-6 and then ask the class how the learners in the nucleus could demonstrate alpha emission.
4. Discuss how the nucleus has changed and whether it is still a polonium-215 nucleus. Students should draw the conclusion that polonium-215 is now a nucleus of lead–211. Students will use this information to complete the chemical equation for the decay of polonium-215.

$$^{215}_{84}Po \rightarrow {}^{211}_{82}Pb + {}^{4}_{2}He$$

Key points to address with students:

- Have any particles been destroyed during this process? Students should be able to prove that the final number of protons and neutrons is identical to the initial number.
- The mass numbers and atomic numbers on both sides of a nuclear equation must always be equal.

5. Understanding can be consolidated using the "task 1 alpha decay equation cards" from the student lab resource.

Role play Activity 2: Examining the radioactive decay of Polonium-215 nucleus by beta emission.

1. Review the answer to pre-lab question 7-9
   Discuss with the class how this type of emission can be modeled using the electron, proton and neutron cards.
2. Select ten new 'sub-atomic particle' volunteers to construct another polonium-215 nucleus. Ensure once again that the single neutron cards are held by two students.

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3. Give each pair of students holding the single neutron cards an envelope. These learners will open the envelope to reveal the contents (or lack thereof).
4. Once the envelopes are opened, discuss the meaning, guiding the discussion towards the conclusion that the neutron with no charge, has split into a positively charged proton and a negatively charged electron.
5. Remove the neutron card from the pair of students who held the envelope containing the electron and proton cards and ask the class if there is anything wrong with this nucleus. Students should be able to identify the electron as not belonging in the nucleus – this particle should then be ejected.
6. Discuss how the nucleus has changed and whether it is still a polonium-215 nucleus.
   Once the class has arrived at the conclusion that it is now a nucleus of astatine-215, students should then complete the nuclear equation for beta emission.

$$^{215}_{84}Po \rightarrow {}^{215}_{85}At + {}^{0}_{-1}e$$

7. Consolidate understanding of beta emission by students completing “task 2 Beta decay equations” card matching activity.

Role play Activity 3: Examining the radioactive decay of Polonium-215 nucleus by gamma radiation

1. Revise the nature of gamma radiation and answer pre-lab questions 10-11.
   The discussion should lead to the conclusion that gamma radiation has no mass and no charge and has the symbol $^{0}_{0}\gamma$. Students can then be asked how the emission of gamma radiation would affect the nucleus of an atom.
2. Consolidate understanding by discussing with the class how gamma decay could be illustrated using the role-play model.

Extension activity sheet

1. This activity involves working out the decay chain for thorium-232 then arranging the decay equation cards in the correct order. This activity is useful as a group challenge activity for groups, although it could be carried out on an individual basis for advanced students.

2. The second extension activity builds on the first and considers the decay chain for uranium-235. It challenges students to work out how it may decay to form a stable element.