1 The nucleus of one of the isotopes of nickel is represented by $^{60}_{28}\text{Ni}$.

Which line in the table correctly describes a neutral atom of this isotope?

<table>
<thead>
<tr>
<th></th>
<th>number of protons</th>
<th>number of neutrons</th>
<th>number of orbital electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>28</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>28</td>
<td>60</td>
<td>28</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>D</td>
<td>60</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

2 A nucleus of bohrium $^{x}_y\text{Bh}$ decays to mendelevium $^{255}_{101}\text{Md}$ by a sequence of three $\alpha$-particle emissions.

bohrium $^{x}_y\text{Bh} \rightarrow$ dubnium + $\alpha$

$\rightarrow$ lawrencium + $\alpha$

$\rightarrow$ mendelevium $^{255}_{101}\text{Md} + \alpha$

How many neutrons are there in a nucleus of $^{x}_y\text{Bh}$?

A 267  
B 261  
C 160  
D 154

3 Which set of radioactive emissions corresponds to the descriptions given in the table headings?

<table>
<thead>
<tr>
<th></th>
<th>high-speed electrons</th>
<th>high-speed helium nuclei</th>
<th>high-frequency photons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$\alpha$</td>
<td>$\beta$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>B</td>
<td>$\alpha$</td>
<td>$\gamma$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>C</td>
<td>$\beta$</td>
<td>$\alpha$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>D</td>
<td>$\beta$</td>
<td>$\gamma$</td>
<td>$\alpha$</td>
</tr>
</tbody>
</table>
4 Strontium-90 ($^{90}_{38}$Sr) is radioactive and emits $\beta$-particles.

Which equation could represent this nuclear decay?

A $^{90}_{38}$Sr $\rightarrow$ $^{90}_{38}$Sr $+ \beta$
B $^{90}_{38}$Sr $\rightarrow$ $^{90}_{37}$Y $+ \beta$
C $^{90}_{38}$Sr $\rightarrow$ $^{90}_{37}$Rb $+ \beta$
D $^{90}_{38}$Sr $\rightarrow$ $^{90}_{37}$Sr $+ \beta$

5 Protons and neutrons are thought to consist of smaller particles called quarks.

The ‘up’ quark has a charge of $\frac{2}{3}e$: a ‘down’ quark has a charge of $-\frac{1}{3}e$, where $e$ is the elementary charge ($+1.6 \times 10^{-19}$C).

How many up quarks and down quarks must a proton contain?

<table>
<thead>
<tr>
<th>up quarks</th>
<th>down quarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
</tr>
</tbody>
</table>

6 A nucleus of the nuclide $^{241}_{94}$Pu decays by emission of a $\beta$-particle followed by the emission of an $\alpha$-particle.

Which of the nuclides shown is formed?

A $^{239}_{93}$Np
B $^{239}_{91}$Pa
C $^{237}_{93}$Np
D $^{237}_{92}$U

7 Which two nuclei contain the same number of neutrons?

A $^{12}_{6}$C and $^{14}_{6}$C
B $^{16}_{7}$N and $^{15}_{8}$O
C $^{23}_{11}$Na and $^{24}_{12}$Mg
D $^{32}_{14}$Si and $^{32}_{15}$P
8 A thin gold foil is bombarded with $\alpha$-particles as shown.

The results of this experiment provide information about the

A binding energy of a gold nucleus.
B energy levels of electrons in gold atoms.
C size of a gold nucleus.
D structure of a gold nucleus.

9 Isotopes of a given element all have the same

A charge/mass ratio.
B neutron number.
C nucleon number.
D proton number.

10 The following represents a sequence of radioactive decays involving two $\alpha$-particles and one $\beta$-particle.

$^{217}_{85}$At $\xrightarrow{\alpha} V \xrightarrow{\alpha} W \xrightarrow{\beta} X$

What is the nuclide X?

A $^{213}_{85}$At
B $^{215}_{77}$Ir
C $^{209}_{82}$Pb
D $^{217}_{81}$Tl
11 A student conducts an experiment using an $\alpha$-particle source.

When considering safety precautions, what can be assumed to be the maximum range of $\alpha$-particles in air?

A  between 0 and 5 mm  
B  between 5 mm and 200 mm  
C  between 200 mm and 500 mm  
D  between 500 mm and 1000 mm

12 What is a correct order of magnitude estimate for the diameter of a typical atomic nucleus?

A  $10^{-14}$ m  
B  $10^{-18}$ m  
C  $10^{-22}$ m  
D  $10^{-26}$ m

13 The decay of a nucleus of neptunium is accompanied by the emission of a $\beta$-particle and $\gamma$-radiation.

What effect (if any) does this decay have on the proton number and the nucleon number of the nucleus?

<table>
<thead>
<tr>
<th></th>
<th>proton number</th>
<th>nucleon number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>increases</td>
<td>decreases</td>
</tr>
<tr>
<td>B</td>
<td>decreases</td>
<td>increases</td>
</tr>
<tr>
<td>C</td>
<td>unchanged</td>
<td>decreases</td>
</tr>
<tr>
<td>D</td>
<td>increases</td>
<td>unchanged</td>
</tr>
</tbody>
</table>

14 Radon-220 is radioactive and decays to Polonium-216 with the emission of an $\alpha$-particle. The equation for the radioactive decay is shown.

$^{220}_{86}\text{Rn} \rightarrow ^{216}_{84}\text{Po} + ^4_2\text{He}$

How many neutrons are in the radon and polonium nuclei?

<table>
<thead>
<tr>
<th></th>
<th>Rn</th>
<th>Po</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>86</td>
<td>84</td>
</tr>
<tr>
<td>B</td>
<td>134</td>
<td>132</td>
</tr>
<tr>
<td>C</td>
<td>220</td>
<td>212</td>
</tr>
<tr>
<td>D</td>
<td>220</td>
<td>216</td>
</tr>
</tbody>
</table>
A detector is exposed to a radioactive source. Fluctuations in the count-rate are observed.

What do these fluctuations indicate about radioactive decay?

A  It is random.
B  It is spontaneous.
C  It is exponential.
D  It is non-linear.

The symbol \( ^{77}_{32}\text{Ge} \) represents a nucleus of germanium that decays to a nucleus of arsenic by emitting a \( \beta \)-particle.

What is the symbol of this arsenic nucleus?

A  \( ^{76}_{32}\text{As} \)
B  \( ^{78}_{32}\text{As} \)
C  \( ^{76}_{31}\text{As} \)
D  \( ^{77}_{33}\text{As} \)

Each of the nuclei below is accelerated from rest through the same potential difference.

Which one completes the acceleration with the lowest speed?

A  \(^1\text{H}\)
B  \(^4\text{He}\)
C  \(^7\text{Li}\)
D  \(^9\text{Be}\)

A radioactive nucleus is formed by \( \beta \)-decay. This nucleus then decays by \( \alpha \)-emission.

Which graph of proton number \( Z \) plotted against nucleon number \( N \) shows the \( \beta \)-decay followed by the \( \alpha \)-emission?
19. What is the approximate mass of a nucleus of uranium?
   A. $10^{-15}$ kg  
   B. $10^{-20}$ kg  
   C. $10^{-25}$ kg  
   D. $10^{-30}$ kg

20. The numbers of protons, neutrons and nucleons in three nuclei are shown.

<table>
<thead>
<tr>
<th>nucleus</th>
<th>number of protons</th>
<th>number of neutrons</th>
<th>number of nucleons</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>15</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>Y</td>
<td>15</td>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td>Z</td>
<td>16</td>
<td>16</td>
<td>32</td>
</tr>
</tbody>
</table>

Which nuclei are isotopes of the same element?
   A. X and Y   
   B. X and Z   
   C. Y and Z   
   D. none of them

21. In an experiment to investigate the nature of the atom, a very thin gold film was bombarded with $\alpha$-particles.

What pattern of deflection of the $\alpha$-particles was observed?
   A. A few $\alpha$-particles were deflected through angles greater than a right angle.  
   B. All $\alpha$-particles were deflected from their original path. 
   C. Most $\alpha$-particles were deflected through angles greater than a right angle. 
   D. No $\alpha$-particle was deflected through an angle greater than a right angle.

22. When a nucleus of $^{238}_{92}$U absorbs a slow neutron it subsequently emits two $\beta$-particles.

What is the resulting nucleus?
   A. $^{240}_{93}$Np   
   B. $^{240}_{91}$Pa   
   C. $^{239}_{94}$Pu   
   D. $^{239}_{90}$Th

23. Which conclusion can be drawn from the results of the experiment showing the scattering of $\alpha$-particles by gold foil?
   A. Electrons orbit the atomic nucleus in well-defined paths.  
   B. Nuclei of different isotopes contain different numbers of neutrons. 
   C. The atomic nucleus contains protons and neutrons. 
   D. The nucleus is very small compared with the size of the atom.
24 A nickel nucleus \(^{58}_{28}\)Ni can be transformed by a process termed K-capture. In this process the nucleus absorbs an orbital electron.

If no other process is involved, what is the resulting nucleus?

A \(^{58}_{28}\)Ni  B \(^{58}_{27}\)Co  C \(^{59}_{27}\)Co  D \(^{59}_{29}\)Cu

25 An atomic nucleus emits a \(\beta\)-particle.

What change does this cause to the proton and nucleon numbers of the nucleus?

<table>
<thead>
<tr>
<th></th>
<th>proton number</th>
<th>nucleon number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>C</td>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>D</td>
<td>+1</td>
<td>0</td>
</tr>
</tbody>
</table>

26 Which are the correct descriptions of a \(\gamma\)-ray and a \(\beta\)-particle?

<table>
<thead>
<tr>
<th></th>
<th>(\gamma)-ray</th>
<th>(\beta)-particle</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>high-speed electron</td>
<td>electromagnetic radiation</td>
</tr>
<tr>
<td>B</td>
<td>electromagnetic radiation</td>
<td>Helium-4 nucleus</td>
</tr>
<tr>
<td>C</td>
<td>electromagnetic radiation</td>
<td>high-speed electron</td>
</tr>
<tr>
<td>D</td>
<td>high-speed electron</td>
<td>Helium-4 nucleus</td>
</tr>
</tbody>
</table>

27 A certain nuclide, Uranium-235, has nucleon number 235, proton number 92 and neutron number 143. Data on four other nuclides are given below.

Which is an isotope of Uranium-235?

<table>
<thead>
<tr>
<th></th>
<th>nucleon number</th>
<th>proton number</th>
<th>neutron number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>235</td>
<td>91</td>
<td>144</td>
</tr>
<tr>
<td>B</td>
<td>236</td>
<td>92</td>
<td>144</td>
</tr>
<tr>
<td>C</td>
<td>237</td>
<td>94</td>
<td>143</td>
</tr>
<tr>
<td>D</td>
<td>238</td>
<td>95</td>
<td>143</td>
</tr>
</tbody>
</table>
28  The symbol $^{77}_{32}\text{Ge}$ represents a nuclide of germanium that decays to a nuclide of arsenic (As) by emitting a $\beta$-particle.

What is the symbol of this arsenic nuclide?

A  $^{76}_{32}\text{As}$  B  $^{78}_{32}\text{As}$  C  $^{78}_{31}\text{As}$  D  $^{77}_{33}\text{As}$

29  The table shows three properties of different types of ionising radiation.

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>charge</td>
<td>0</td>
<td>$-1e$</td>
<td>$+2e$</td>
</tr>
<tr>
<td>mass</td>
<td>0</td>
<td>$\frac{1}{1840}u$</td>
<td>$4u$</td>
</tr>
<tr>
<td>speed</td>
<td>$c$</td>
<td>$\sim0.9c$</td>
<td>$\sim0.1c$</td>
</tr>
</tbody>
</table>

What are the radiations X, Y and Z?

A  $\text{alpha}$  B  $\text{beta}$  C  $\text{gamma}$  D  $\text{X-rays}$

30  A nuclear reaction is represented by the equation

$^{16}_8\text{O} + ^4_2\text{He} \rightarrow ^{19}_9\text{F} + X.$

What is particle X?

A  an $\alpha$-particle  B  a $\beta$-particle  C  a neutron  D  a proton

31  A nucleus Q has the notation $^y_x\text{Q}$.

Which of the following is an isotope of Q?

A  $^y_{x-1}\text{Q}$  B  $^y_{x+1}\text{Q}$  C  $^y_{x+1}\text{Q}$  D  $^y_{x+1}\text{Q}$
32 Two $\alpha$-particles with equal energies are fired towards the nucleus of a gold atom. Which diagram best represents their paths?

A

B

gold nucleus
gold nucleus

c

d

33 How is it possible to distinguish between the isotopes of uranium?

A Their nuclei have different charge and different mass, and they emit different particles when they decay.

B Their nuclei have different charge but the same mass.

C Their nuclei have the same charge but different mass.

D Their nuclei have the same charge and mass, but they emit different particles when they decay.

34 What is not conserved in nuclear processes?

A energy and mass together

B nucleon number

C neutron number

D charge
A thin gold foil is bombarded with \( \alpha \)-particles as shown.

What can be deduced from this experiment?

A. the binding energy of a gold nucleus
B. the energy levels of electrons in gold atoms
C. the small size of a gold nucleus
D. the structure of a gold nucleus

A zirconium nucleus, \( ^{100}_{40} \text{Zr} \), is a \( \beta \)-emitter. The product nucleus is also a \( \beta \)-emitter.

What is the final resulting nucleus of these two decays?

A. \( ^{98}_{40} \text{Zr} \)  
B. \( ^{100}_{42} \text{Mo} \)  
C. \( ^{100}_{38} \text{Sr} \)  
D. \( ^{102}_{40} \text{Zr} \)

The following particles are each accelerated from rest through the same potential difference.

Which one completes the acceleration with the greatest momentum?

A. \( \alpha \)-particle
B. electron
C. neutron
D. proton
37 Radon $^{222}_{86}\text{Rn}$ decays by α– and β–emission to bismuth $^{214}_{83}\text{Bi}$.

For the decay of each nucleus of radon, how many α– and β–particles are emitted?

<table>
<thead>
<tr>
<th></th>
<th>α–particles</th>
<th>β–particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

38 Which conclusion can be drawn from the results of the experiment showing the scattering of α-particles by gold foil?

A Electrons orbit the atomic nucleus in well-defined paths.
B Nuclei of different isotopes contain different numbers of neutrons.
C The atomic nucleus contains protons and neutrons.
D The nucleus is very small compared with the size of the atom.

39 Which statement concerning α-particles is correct?

A An α-particle has charge +4e.
B An α-particle is a helium atom.
C When α-particles travel through air, they cause ionisation.
D When α-particles travel through a sheet of gold foil, they make the gold radioactive.

40 Where are electrons, neutrons and protons found in an atom?

<table>
<thead>
<tr>
<th></th>
<th>electrons</th>
<th>neutrons</th>
<th>protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>in the nucleus</td>
<td>in the nucleus</td>
<td>orbiting the nucleus</td>
</tr>
<tr>
<td>B</td>
<td>in the nucleus</td>
<td>orbiting the nucleus</td>
<td>in the nucleus</td>
</tr>
<tr>
<td>C</td>
<td>orbiting the nucleus</td>
<td>in the nucleus</td>
<td>orbiting the nucleus</td>
</tr>
<tr>
<td>D</td>
<td>orbiting the nucleus</td>
<td>in the nucleus</td>
<td>in the nucleus</td>
</tr>
</tbody>
</table>

41 A $^{238}_{92}\text{U}$ nucleus decays in two stages to a $^{234}_{91}\text{Pa}$ nucleus.

What was emitted in these two stages?

A $\alpha + \beta$  B $\alpha + \gamma$  C $\beta + \beta$  D $\beta + \gamma$