Worked Solutions for ENGAA Papers by Topic

Section 1

Topic: Radioactivity

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ENGAA S1 2020 - Question 3

3 Uranium-238 $\left({}^{238}_{92}\mathrm{U}\right)$ decays by a series of alpha and beta (β^-) emissions to become the stable isotope lead-206 $\left({}^{206}_{82}\mathrm{Pb}\right)$.

How many beta (β^-) particles are emitted in the decay of one uranium-238 nucleus to lead-206?

A 6

B 8

C 10

D 12

E 14

F 16

ENGAA S1 2020 - Question 3 - Worked Solution

β: neutron → proton & β^- electron

$-10\beta \quad 24\alpha$

$92238U \rightarrow 82206pb$

mass decreased by 32 → 8α

charge is conserved:

$92 - 8.2 + n.1 = 82$

$n = 6$

Answer is A

ENGAA S1 2019 - Question 12

12 The radioactive isotope X becomes the stable isotope Y after a succession of decays involving only the emission of alpha and beta (β^-) particles.

During the decay of one nucleus from X to Y, a total of seven particles are emitted. It is known that more of these particles are alpha particles than beta particles.

The atomic number of X is *Z* and the mass number of X is *A*.

Which row in the table could give the atomic number and the mass number of Y?

	atomic number of Y	*mass number of* Y
A	$Z - 2$	$A - 12$
B	$Z - 5$	$A - 8$
C	$Z - 8$	$A - 20$
D	$Z - 10$	$A - 24$
E	$Z - 11$	$A - 16$

ENGAA S1 2019 - Question 12 - Worked Solution

α : Gives alpha particle off $A = -\frac{4}{2} = -2$

β : Neutron → proton + electron

$A = 0 \quad Z = +1$

$ZAX \rightarrow n \times 24\alpha + (7 - n) - 10\beta + ??\,Y$

n, the number of alpha particles gien off is greater than 7 — n

: n = 4,5 or 6 → eliminates first two options , due to mass loss.

plugging C 为 D 为 E into above decay equation

Only C holds

Answer is C

ENGAA S1 2019 - Question 20

20 A sample initially contains equal numbers of atoms of a radioactive isotope X and a stable isotope Y.

Isotope X has a half-life of 3 years and decays in a single stage to the stable isotope Y.

What is the ratio

number of atoms of X : *number of atoms of* Y

in the sample 6 years later?

A The sample contains only isotope Y.

B 1 : 7

C 1 : 4

D 1 : 3

E 7 : 4

ENGAA S1 2019 - Question 20 - Worked Solution

Initially

$\frac{x}{y} = \frac{1}{1}$

After two half lives

$x \rightarrow \frac{1}{4}\, x$

$y \rightarrow \frac{1}{1}\, 4 + \frac{3}{4}\, 4$

$4 \rightarrow \frac{7}{4}\, 4$

Thus ratio is

1 : 7

Answer is B

ENGAA Specimen S1 - Question 12

12 Nuclide ${}^{N}_{R}X$ is an unstable isotope which decays in two stages into nuclide Z as shown:

$$ {}^{N}_{R}X \rightarrow {}^{P}_{R-2}Y \rightarrow {}^{P}_{Q}Z $$

What are the values of P and Q?

(Consider only alpha and beta decays.)

	P	Q
A	$N - 4$	$R + 1$
B	$N - 4$	$R - 1$
C	$N - 4$	$R - 2$
D	N	$R - 1$
E	N	$R - 2$
F	N	$R - 4$

ENGAA Specimen S1 - Question 12 - Worked Solution

RNX → R—2PY → QPz

Since the proton number of Y is 2 less than that of X,

X → Y by alpha decay

hence P = N — 4

Since the mass number of Z is equal **to** that of Y , it decays by beta decay.

hence Q = R — 2 + 1 = R — 1

Answer is B

ENGAA S1 2018 - Question 2

2 An unstable nucleus X becomes a stable nucleus Y after a succession of decays, during which a total of 5 alpha particles and 2 beta (β^-) particles are emitted.

How many fewer protons does nucleus Y contain than nucleus X?

A 6

B 8

C 10

D 12

E 14

F 16

G 18

H 20

ENGAA S1 2018 - Question 2 - Worked Solution

An α particle:

$2^{4}\alpha$

A β particle :

$-^{0}_{1}\beta$

So total number of proton's lost;

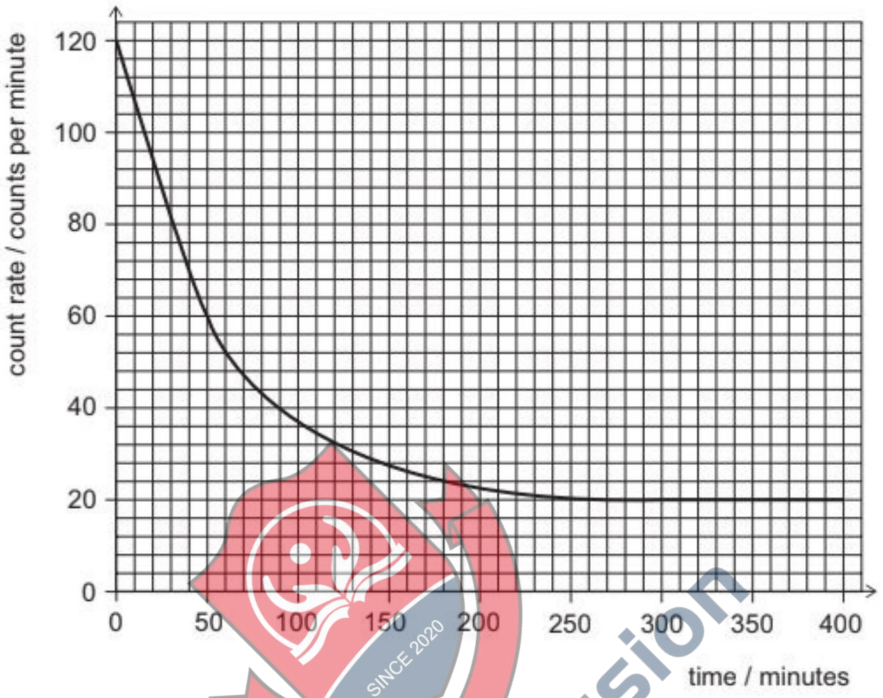
$(5 \times 2) + (-1 \times 2) = 8$

Answer is B.

ENGAA S1 2018 - Question 14

14 A radioactive isotope decays in a single step to a stable isotope.

A radiation detector is placed very near to a sample of the radioactive isotope in a laboratory. The count rate on the detector changes as time elapses. The graph shows how the measured count rate changes with time.



What is the background count rate and what is the half-life of the isotope?

	background count rate / counts per minute	*half-life of isotope* / minutes
A	20	40
B	20	50
C	20	60
D	20	65
E	120	40
F	120	50
G	120	60
H	120	65

ENGAA S1 2018 - Question 14 - Worked Solution

- From graph
  Background counts 20 counts/min
- So initial sample a line has initial count:
  120 - 20 = 100
- At half life will have count : 50
- So total count will be:
  20 + 50 = 70
  From graph this is at : 40 min

Answer is A.

ENGAA S1 2018 - Question 24

24 A neutron is absorbed by a uranium-235 ($^{235}_{92}U$) nuclide.

The resulting nuclide undergoes fission to produce a bromine-88 ($^{88}_{35}Br$) nuclide, a lanthanum-145 nuclide and some neutrons.

The lanthanum-145 nuclide is radioactive and emits a beta (β^-) particle.

How many neutrons are emitted in the fission reaction and how many protons are there in the nuclide formed by the decay of lanthanum-145?

	neutrons	*protons*
A	2	55
B	2	56
C	2	57
D	2	58
E	3	55
F	3	56
G	3	57
H	3	58

ENGAA S1 2018 - Question 24 - Worked Solution

Write decay equation:

$$92235u + 01n \rightarrow 588Br + 57145La + x01n$$

conserve mass number:

$$236 = 88 + 145 + x$$

$$x = 3$$

3 Neutrons

Conserve mass number and proton number of 2nd decay:

$$57145La \rightarrow —10\beta + 58145X$$

58 Protons

Answer is H.

ENGAA S1 2017 - Question 8

8 In one type of medical scanner a source is placed inside a patient's body. This source causes pairs of gamma-rays to be emitted simultaneously in opposite directions.

Detectors on each side of the patient are used to detect the gamma-rays. The distance between the two detectors is 3.0 m. When the source is at Q, half-way between the detectors, the two gamma-rays arrive at the same time.

In a particular scan the gamma-rays arrive at the two detectors with a time difference of 4.0×10^{-10} s.

Assume that, inside the patient, the gamma-rays travel at a speed of $3.0 \times 10^{8}\,\text{m s}^{-1}$.

How far from Q, half-way between the detectors, is the gamma-ray source?

A 6.0 mm

B 12 mm

C 24 mm

D 6.0 cm

E 12 cm

F 24 cm

ENGAA 2017 - Question 8 - Worked Solution

① $L - x = t_1 C$

② $x + L = t_2 C$

Subtract two equations

$x - (-x) = t_2 c - t_1 c$

$2x = c(t_2 - t_1)$

$$x = \frac{C(t_2 - t_1)}{2}$$

$$x = \frac{3.0 \times 10^{8} \times 4.0 \times 10^{-10}}{2}$$

$x = 0.06\text{m}$

$x = 6\text{cm}$

Answer is D

ENGAA S1 2017 - Question 10

10 When a plutonium-239 nucleus absorbs a neutron it undergoes nuclear fission. One particular fission reaction results in the creation of xenon and zirconium as daughter nuclei. The nuclear equation for this reaction is shown but with some non-zero integers replaced by the letters w, x, y and z.

$$ {}^{1}_{0}\mathrm{n} + {}^{239}_{94}\mathrm{Pu} \rightarrow {}^{w}_{54}\mathrm{Xe} + {}^{y}_{x}\mathrm{Zr} + z\,{}^{1}_{0}\mathrm{n} $$

Which equation is correct?

A $w + y = 240$

B $z = 240 - (w + y)$

C $x = 40 - z$

D $94 = 54 + x + 1$

E $240 = 54 + x$

F $94 = w + y + 1$

ENGAA 2017 - Question 10 - Worked Solution

Balance Nucleon Number

$$1 + 239 = w + g + z \times 1$$

$$240 = w + g + z$$

Balance Atomic Numbers

$$0 + 94 = 54 + x + 0$$

$$x = 94 - 54$$

$$x = 40$$

Answer is B

ENGAA S1 2017 - Question 14

14 The nuclide ${}^{P}_{Q}X$ decays to the stable nuclide Y. During this process four particles are emitted: an α-particle and three β^- particles.

Which of the following is **not** a nuclide that could be formed at any stage during this process?

nuclide	*atomic mass*	*atomic number*
A	P	Q – 1
B	P	Q + 1
C	P	Q + 2
D	P	Q + 3
E	P – 4	Q – 2
F	P – 4	Q – 1
G	P – 4	Q
H	P – 4	Q + 1

ENGAA 2017 - Question 14 - Worked Solution

$-\alpha$ particles:

${}^{4}_{2}\alpha$

β^- particle
An electron

${}^{0}_{-1}\beta$

- Atomic and mass number need to always balanced
- A is not possible as:
  Atomic mass is P , so would describe a nuclei atom pre α emission
- But $\alpha - 1$ is not possible as a β^- decay would causes atomic number of nuclide to increase

Answer is A

ENGAA S1 2017 - Question 26

26 Two radioactive sources X and Y have half-lives of 3.0 hours and 2.0 hours respectively. The product of the decay of both of the sources is a stable isotope of the element Z.

Six hours ago a mixture contained the same number of atoms of both X and Y, and no other atoms.

What fraction of the mixture is now made up of atoms of Z?

A $\frac{10}{16}$

B $\frac{11}{16}$

C $\frac{12}{16}$

D $\frac{13}{16}$

E $\frac{14}{16}$

F $\frac{15}{16}$

ENGAA S1 2017 - Question 26 - Worked Solution

- Initially $N_x = N$, $N_Y = N$
- In 6 hours:
  - Two half lives of X:

$$N_x = \frac{N}{4}$$

  - Three half lives of Y:

$$N_Y = \frac{N}{8}$$

$$\rightarrow N_z = (N - N_x) + (N - N_y)$$

$$= 2N - \frac{N}{4} - \frac{N}{8}$$

$$= \frac{13}{8}N$$

$$\Rightarrow \frac{N_Z}{N_Z + N_X + N_Y} = \frac{\frac{13}{8}}{\frac{13}{8} + \frac{1}{4} + \frac{1}{8}}$$

$$= \frac{13}{8 \times 2}$$

$$= \frac{13}{16}$$

Answer is D

ENGAA S1 2016 - Question 2

A nuclide $^{214}_{82}Pb$ changes by radioactive decay into the nuclide $^{210}_{82}Pb$.
Which combination of emissions produces this change?

A 3 alpha

B 2 alpha and 1 beta

C 2 alpha and 2 beta

D 1 alpha and 2 beta

E 3 beta

ENGAA S1 2016 - Question 2 - Worked Solution

$$82214pb \rightarrow \ldots \rightarrow 82210pb + \ldots$$

The lead-214 nuclide loses 4 nucleons so it emits 1 alpha particle. This would result in a nuclide

$$80210X$$

The proton number then increases by 2. This means 2 beta decays occur

$$1\,\alpha \text{ and } 2\,\beta$$

Answer is D

ENGAA S1 2016 - Question 6

6 A uranium-235 nucleus can undergo fission to produce two smaller nuclei.

Which of the diagrams, if any, could represent this process?

diagram 1

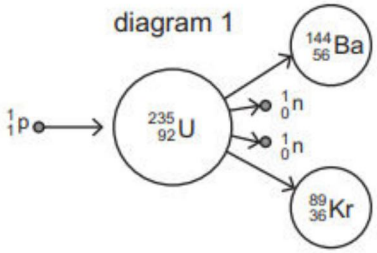


diagram 2

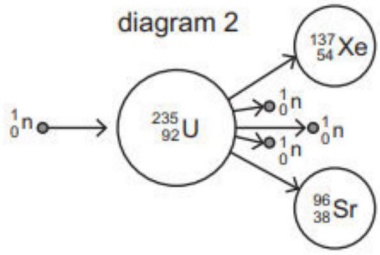
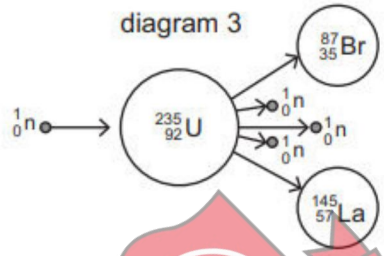


diagram 3



A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

ENGAA S1 2016 - Question 6 - Worked Solution

Diagram 1

$$92235U + 11P \rightarrow 2 \times 01n + 55144Ba + 3689kr$$

The number of protons is not constant,

The nucleon number is also not constant

This is not possible

Diagram 2

$$^{235}_{92}U + ^{1}_{0}n \rightarrow 3 \times ^{1}_{0}n + ^{96}_{38}Sr + ^{137}_{54}Xe$$

The number of proton and nucleons is constant

This is possible

Diagram 3

$$^{1}_{0}n + ^{235}_{92}U \rightarrow 3 \times ^{1}_{0}n + ^{87}_{35}Br + ^{145}_{57}La$$

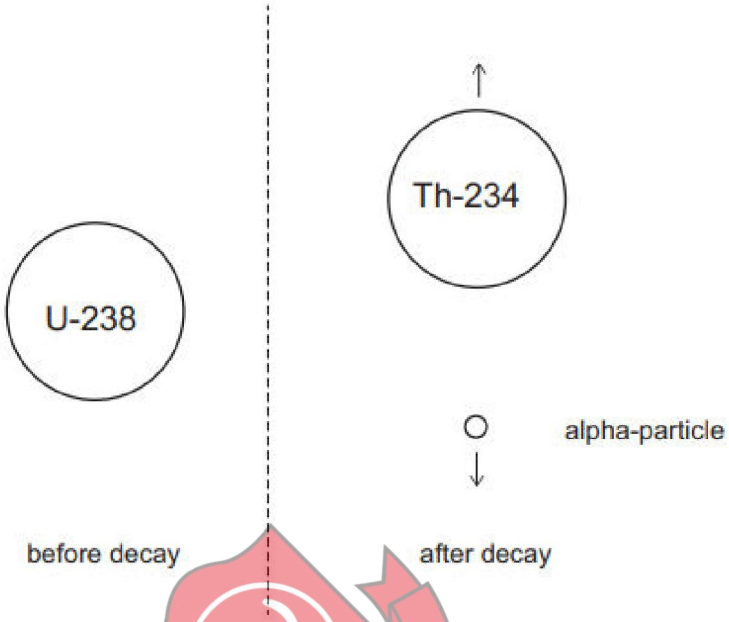
This is not possible

2 only

Answer is C

ENGAA S1 2016 - Question 26

26 When a stationary uranium-238 nucleus decays by alpha emission it forms a nucleus of thorium-234. The total kinetic energy produced by the decay is *E*.



What is the kinetic energy of the alpha particle?

A $\frac{4E}{238}$

B $\frac{4E}{234}$

C $\frac{E}{2}$

D $\frac{234E}{238}$

E E

ENGAA S1 2016 - Question 26 - Worked Solution

The α particles has a relative mass of 4 and the Th - 234 has a relative mass of 234

By conservation of momentum

$$4V_\alpha = 234V_T$$

$$V_T = \frac{4}{234}V_\alpha$$

$$\frac{1}{2} \times 4 \times V_\alpha^2 + \frac{1}{2} \times 234 \times V_T^2 = E$$

$$2v_\alpha^2 + \frac{1}{2} \times 234 \times \left(\frac{4}{234}\right)^2 v_\alpha^2 = E$$

$$E_\alpha = 2v_\alpha^2$$

$$E = v_\alpha^2 \left(2 + \frac{8}{234}\right)$$

$$E_\alpha = \frac{2E}{2 + \frac{8}{234}} = \frac{234}{238} E$$

Answer is D