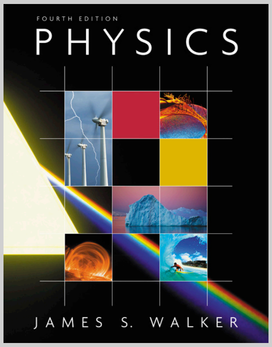


ConcepTest Clicker Questions

Chapter 32

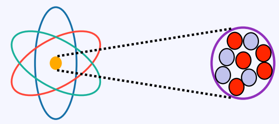
Physics, 4^{th} Edition

James S. Walker

Question 32.1 The Nucleus

There are 82 protons in a lead nucleus. Why doesn't the lead nucleus burst apart?

a) Coulomb repulsive force doesn't act inside the nucleus
b) gravity overpowers the Coulomb repulsive force inside the nucleus
c) the negatively charged neutrons balance the positively charged protons
d) protons lose their positive charge inside the nucleus
e) none of the above



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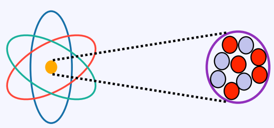
d) protons lose their positive charge inside the nucleus
e) none of the above

The Coulomb repulsive force is overcome by the even stronger ***nuclear force***!



Question 32.2a Binding Energy I

What weighs more, an electron and a proton, or a hydrogen atom?

a) electron and proton
b) hydrogen atom
c) both the same

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The total energy (or mass) of a hydrogen atom must be *less* than the energies (or masses) of the electron plus the proton individually in order for the electron to be bound.

Question 32.2b Binding Energy II

What is the total energy (or mass) of the hydrogen atom in its ground state?

a) 13.6 eV
b) $m_pc^2 + m_ec^2 + 13.6$ eV
c) $m_pc^2 + m_ec^2$
d) $m_pc^2 + m_ec^2 - 13.6$ eV

Question 32.2b — Binding Energy II

What is the total energy (or mass) of the hydrogen atom in its ground state?

a) 13.6 eV

b) $m_p c^2 + m_e c^2 + 13.6$ eV

c) $m_p c^2 + m_e c^2$

d) $m_p c^2 + m_e c^2 - 13.6$ eV

The total energy (or mass) of a hydrogen atom must be *less* than the energies (or masses) of the electron plus the proton individually in order for the electron to be bound. The mass difference is the binding energy.

Question 32.2c — Binding Energy III

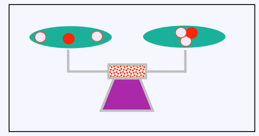
On a balance scale, you put 2 neutrons and 1 proton on one side and you put a tritium nucleus (^{3}H) on the other. Which side weighs more?

a) the 2 neutrons and 1 proton

b) the tritium nucleus

c) they both weigh the same

d) it depends on the specific isotope of tritium



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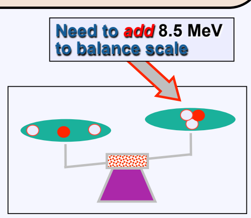
a) the 2 neutrons and 1 proton

b) the tritium nucleus

c) they both weigh the same

d) it depends on the specific isotope of tritium

The mass of the 2 neutrons and 1 proton is *less* when they are bound together as tritium. The mass difference is the binding energy.



Question 32.3 — Separation Energy

Does it take more energy to remove one proton or one neutron from ^{16}O?

a) removing a proton takes more energy

b) removing a neutron takes more energy

c) both take the same amount of energy

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Does it take more energy to remove one proton or one neutron from ^{16}O?

a) removing a proton takes more energy

b) removing a neutron takes more energy

c) both take the same amount of energy

Removing a proton takes *less* energy because the repulsive Coulomb force between positively charged protons helps to push the proton out of the nucleus. Remember that neutrons are uncharged.

Question 32.4 — Nuclear Reaction Products

What is the nucleus that results in the reaction given below?

$$n + {}^{16}_{8}\mathrm{O} \rightarrow ? + {}^{2}_{1}\mathrm{H}$$

a) ${}^{17}_{8}\mathrm{O}$

b) ${}^{15}_{7}\mathrm{O}$

c) ${}^{15}_{7}\mathrm{N}$

d) ${}^{15}_{7}\mathrm{F}$

$${}^{A}_{Z}X$$

Question 32.4 Nuclear Reaction Products

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b) ${}^{15}_{7}\mathrm{O}$
c) ${}^{15}_{7}\mathrm{N}$
d) ${}^{15}_{7}\mathrm{F}$

Add up the totals for nucleons (*A*) and protons (*Z*) separately, and see what you need to balance both sides:

Nucleons: 1 + 16 = *x* + 2 ⇒ *x* = 15

Protons: 0 + 8 = *y* + 1 ⇒ *y* = 7

The missing nucleus has *A* = 15 and *Z* = 7.

$${}^{A}_{Z}\mathrm{X}$$

Follow-up: What would you get if you started with *p* + ^{16}O instead?

Question 32.5 Nuclear Reactions

What is the *Q*-value for radioactive decay reactions?

a) *Q* < 0
b) *Q* > 0
c) *Q* = 0
d) sign of *Q* depends on the nucleus

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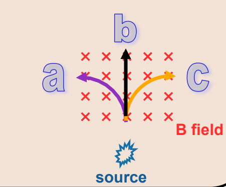
b) *Q* > 0
c) *Q* = 0
d) sign of *Q* depends on the nucleus

Radioactive decay happens ***spontaneously*** because the nucleus can reach a lower energy state. Thus, such reactions can only occur spontaneously if they ***release energy*** (***exothermic***), so the *Q*-value is positive

Follow-up: Is radioactive decay an endothermic or exothermic reaction?

Question 32.6a Particle Emission I

A radioactive substance decays and the emitted particle passes through a uniform magnetic field pointing into the page as shown. In which direction are alpha particles deflected?



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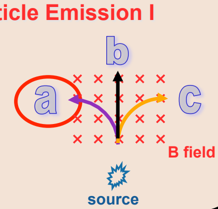
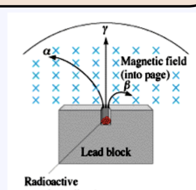
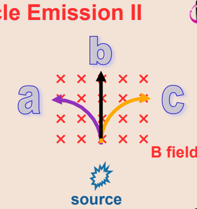


Using the right-hand rule, we find that positively charged particles (alpha particles) are deflected to the left.



Question 32.6b Particle Emission II

A radioactive substance decays and the emitted particle passes through a uniform magnetic field pointing into the page as shown. In which direction are gamma rays deflected?



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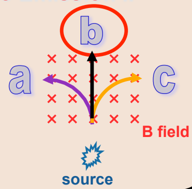
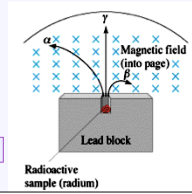


Gamma rays are uncharged so they will not be deflected by a magnetic field.



Follow-up: What particles are bent to the right?

Question 32.7 Radioactive Decay Energy

A radioactive nucleus undergoes gamma decay. How large would you expect the energy of the emitted photon to be?

a) less than 13.6 eV
b) 13.6 eV
c) hundreds of eV
d) millions of eV
e) billions of eV

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a) less than 13.6 eV
b) 13.6 eV
c) hundreds of eV
d) millions of eV
e) billions of eV

The binding energy of nuclei is of the order of *several MeV* (millions of eV). So, we would expect the energy of gamma decay to be in the same ballpark.

Follow-up: What process could release a photon with billions of eV?

Question 32.8a Alpha Decay I

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater momentum?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

Question 32.8a Alpha Decay I

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater momentum?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

By momentum conservation, they must have the same magnitude of momentum since the initial momentum was zero.

Follow-up: In what directions are the two products emitted?

Question 32.8b Alpha Decay II

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater velocity?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

Question 32.8b Alpha Decay II

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater velocity?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

The momentum is *mv* and is the same for both, but the alpha particle has the smaller mass so it has the larger velocity.

Question 32.8c Alpha Decay III

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater kinetic energy?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

Question 32.8c Alpha Decay III

A uranium nucleus ^{238}U (initially at rest) decays into a thorium nucleus ^{234}Th and an alpha particle. Which one has the greater kinetic energy?

a) the ^{234}Th nucleus
b) the alpha particle
c) both the same

The kinetic energy $1/2mv^2$ can be written as $KE = p^2/2m$. The momentum is the same for both, but the alpha particle has the smaller mass so it has the larger KE.

Question 32.9 Beta Decay

What element results when ^{14}C undergoes beta decay?

a) ^{15}C
b) ^{15}N
c) ^{14}C
d) ^{14}N
e) ^{15}O

Question 32.9 Beta Decay

What element results when ^{14}C undergoes beta decay?

a) ^{15}C
b) ^{15}N
c) ^{14}C
d) ^{14}N
e) ^{15}O

The reaction is: $^{14}_{6}C \rightarrow ^{14}_{7}N + e^- + \text{neutrino}$

Inside the nucleus, the reaction $n \rightarrow p + e^- + \nu$ has occurred, changing a neutron into a proton so the atomic number Z increases by 1. However the mass number (A = 14) stays the same.

Follow-up: How would you turn ^{14}C into ^{15}N?

Question 32.10a Radioactive Decay Law I

You have 16 kg of a radioactive sample with a certain half-life of 30 years. How much is left after 90 years?

a) 8 kg
b) 4 kg
c) 2 kg
d) 1 kg
e) nothing

Question 32.10a — Radioactive Decay Law I

You have 16 kg of a radioactive sample with a certain half-life of 30 years. How much is left after 90 years?

a) 8 kg
b) 4 kg
c) 2 kg
d) 1 kg
e) nothing

The total time (90 years) is 3 half-lives
After one half-life ⇒ 8 kg left.
After two half-lives ⇒ 4 kg left.
After three half-lives ⇒ 2 kg left

Follow-up: When will the sample be reduced to nothing?

Question 32.10b — Radioactive Decay Law II

You have 12 kg of a radioactive substance. Ten years later, you find that you only have 3 kg left. Find the half-life of the material.

a) 20 years
b) 10 years
c) 7.5 years
d) 5 years
e) 2.5 years

Question 32.10b — Radioactive Decay Law II

You have 12 kg of a radioactive substance. Ten years later, you find that you only have 3 kg left. Find the half-life of the material.

a) 20 years
b) 10 years
c) 7.5 years
d) 5 years
e) 2.5 years

After one half-life ⇒ 6 kg left.
After two half-lives ⇒ 3 kg left.
So if the total time is 10 years,
then the half-life must be 5 years.
(2 half-lives = 10 years)

Follow-up: How much of the sample is left after another 10 years?

Question 32.10c — Radioactive Decay Law III

You have 400 g of a radioactive sample with a half-life of 20 years. How much is left after 50 years?

a) more than 100 g
b) 75 – 100 g
c) 75 g
d) 50 – 75 g
e) less than 50 g

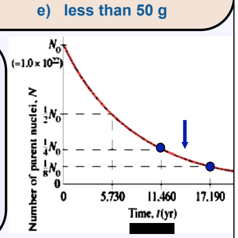
Question 32.10c — Radioactive Decay Law III

You have 400 g of a radioactive sample with a half-life of 20 years. How much is left after 50 years?

a) more than 100 g
b) 75 – 100 g
c) 75 g
d) 50 – 75 g
e) less than 50 g

Total time (50 years) is 2 1/2 half-lives.
After one half-life ⇒ 200 g left
After two half-lives ⇒ 100 g left.
After three half-lives ⇒ 50 g left.
So after 2 1/2 half-lives ⇒ 75 g left ?
No!! Exponential function is not linear!

$N = N_o(1/2)^{t/t_{1/2}}$ ⇒ 70.7 g left



Question 32.10d — Radioactive Decay Law IV

You have two samples, A ($T_{1/2}$ = 10 yr) and B ($T_{1/2}$ = 20 yr), with initially different amounts. The initial amount of sample A is *64 kg* while the amount of sample B is unknown. If you observe that the 2 amounts are equal after 40 years, what is the initial amount of B?

a) 64 kg
b) 32 kg
c) 16 kg
d) 8 kg
e) 4 kg

Question 32.10d — Radioactive Decay Law IV

You have two samples, A ($T_{1/2}$ = 10 yr) and B ($T_{1/2}$ = 20 yr), with initially different amounts. The initial amount of sample A is *64 kg* while the amount of sample B is unknown. If you observe that the 2 amounts are equal after 40 years, what is the initial amount of B?

a) 64 kg
b) 32 kg
c) 16 kg
d) 8 kg
e) 4 kg

For sample A, after 40 years (4 half-lives) there are 4 kg left. Now work backward from there, for sample B: 40 years is 2 half-lives so sample B initially had 16 kg.

Follow-up: When will the samples again have equal amounts?

Question 32.11a — Activity and Half-Life I

You have 10 kg each of a radioactive sample A with a half-life of 100 years, and another sample B with a half-life of 1000 years. Which sample has the higher activity?

a) sample A
b) sample B
c) both the same
d) impossible to tell

Question 32.11a — Activity and Half-Life I

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a) sample A
b) sample B
c) both the same
d) impossible to tell

If a sample has a shorter half-life, this means that it decays more quickly (larger decay constant λ) and therefore has a higher activity: $\Delta N/\Delta t = -rN$

In this case, that is sample A.

Follow-up: What is the ratio of activities for the two samples?

Question 32.11b — Activity and Half-Life II

The same amount of two different radioactive samples A and B is prepared. If the initial activity of sample A is 5 times larger than that of sample B, how do their half-lives compare?

a) $T_{1/2}$ of A is 5 times larger than B
b) half-lives are the same
c) $T_{1/2}$ of A is 5 times smaller than B

Question 32.11b — Activity and Half-Life II

The same amount of two different radioactive samples A and B is prepared. If the initial activity of sample A is 5 times larger than that of sample B, how do their half-lives compare?

a) $T_{1/2}$ of A is 5 times larger than B
b) half-lives are the same
c) $T_{1/2}$ of A is 5 times smaller than B

A larger activity means that a sample decays more quickly, and this implies a shorter half-life.

Question 32.12 — Nuclear Fission

How does the total mass of the fission fragments compare to the mass of the original nucleus in a fission reaction?

a) fission fragments have more mass
b) fission fragments have less mass
c) fission fragments have the same mass

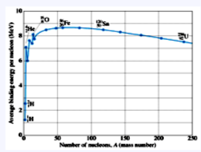
Question 32.12 Nuclear Fission

How does the total mass of the fission fragments compare to the mass of the original nucleus in a fission reaction?

a) fission fragments have more mass
b) fission fragments have less mass
c) fission fragments have the same mass

The fission reaction releases energy, so the total energy (or mass) of the fission fragments must be less than the energy (or mass) of the original nucleus.

Follow-up: Where are the fission fragments located relative to the original nucleus on the curve of binding energy per nucleon?



Question 32.13 Nuclear Fusion

How does the binding energy per nucleon of a fusion product compare to that of the pieces that combined to form it?

a) product has greater BE than the pieces
b) product has less BE than the pieces
c) product has the same BE as the pieces

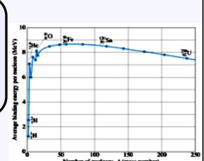
Question 32.13 Nuclear Fusion

How does the binding energy per nucleon of a fusion product compare to that of the pieces that combined to form it?

a) product has greater BE than the pieces
b) product has less BE than the pieces
c) product has the same BE as the pieces

The fusion reaction releases energy so the product is more tightly bound (more stable) than the separate pieces that combined to form it. This means that the binding energy per nucleon is greater for the fusion product

Follow-up: Which weighs more: the fusion product or the pieces?



Question 32.14 Radiation Shielding

Which type of radiation goes farther in matter before losing all of its energy ?

a) alpha radiation
b) beta radiation
c) gamma radiation
d) all about the same distance

Question 32.14 Radiation Shielding

Which type of radiation goes farther in matter before losing all of its energy ?

a) alpha radiation
b) beta radiation
c) gamma radiation
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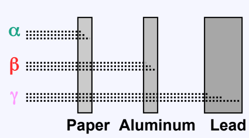
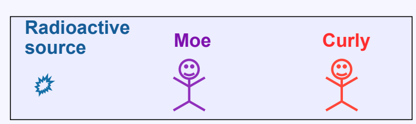
Alpha particles have such a large charge that they ionize many atoms in a short distance, and so lose their energy rapidly and stop. Gamma rays travel great distances before ionizing an atom.



Question 32.15a Radiation Exposure I

Curly is twice as far from a small radioactive source as Moe. Compared to Curly's position, the intensity of the radiation (and therefore exposure) at Moe's position is about:

a) one-quarter
b) one-half
c) the same
d) double
e) quadruple



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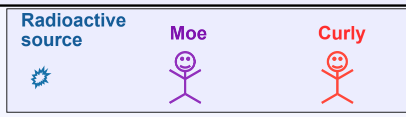
a) one-quarter
b) one-half
c) the same
d) double
e) quadruple

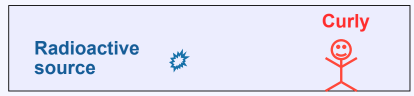
A small source can be treated as a point source and so it obeys the inverse square law of intensity. Twice as close means 4 times the intensity (and therefore exposure).



Question 32.15b Radiation Exposure II

Curly is working 5 m from a highly radioactive source and must reduce his exposure by at least a factor of 10. Assuming that an inverse square law ($1/r^2$) applies in this case, to what distance should he move?

a) 7.5 m
b) 10 m
c) 15 m
d) 20 m
e) 50 m



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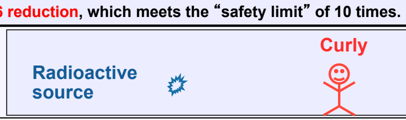
a) 7.5 m
b) 10 m
c) 15 m
d) 20 m
e) 50 m

A small source can be treated like a point source and so it obeys the inverse square law of intensity. Moving to 15 m 3 times farther) reduces the exposure by only 9 times. He has to move farther away (20 m) in order to get a factor of 16 reduction, which meets the "safety limit" of 10 times.



Question 32.16 Radiation Damage

Radiation can damage matter such as metals or biological tissue by:

a) heating up the material
b) causing cancer in the metal
c) producing fission reactions in the material
d) removing electrons from the atoms
e) producing fusion reactions in the material

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Radiation can ionize the atoms in matter, which means knocking out electrons. Metals become brittle and cell processes can be disrupted.

Follow-up: What type of radiation will tend to do the most damage?