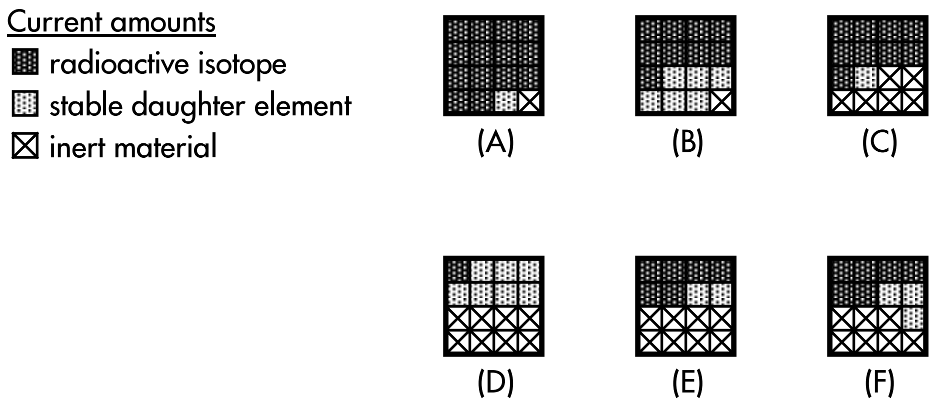
Samples have certain amounts of a radioactive isotope, an embedded gaseous daughter element (which is the byproduct of the radioactive decay process), and inert material (which is not involved in the decay process).



1. For each sample, count the *current* number of radioactive squares it has *right now*.

2. For each sample, determine the *original* number of radioactive squares that it had *when it first solidified*.

3. For each sample, calculate the percentage of *original* radioactive squares that are still *currently* radioactive *right now*.

4. Rank the samples from least to most radioactivity detected *right now*. Indicate ties, if any.

________ ________ ________ ________ ________ ________

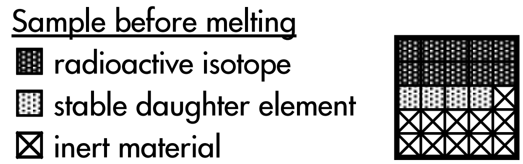
(least radioactivity) (most radioactivity)

5. Rank the samples from longest ago (oldest) to most recent (youngest) solidification age. Indicate ties, if any.

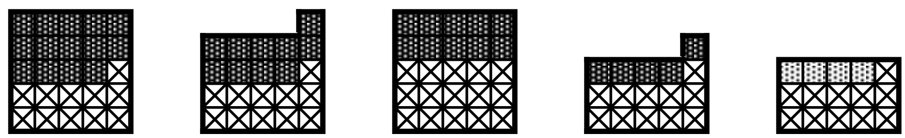
________ ________ ________ ________ ________ ________

(oldest) (youngest)

6. A sample has certain amounts of a radioactive isotope, embedded gaseous daughter element (which is the byproduct of the radioactive decay process), and inert material (which is not involved in the decay process).



This sample is melted completely, and then cooled and solidified. What is the composition of the sample *after* it has resolidified?



(A) (B) (C) (D) (E)

(F) (Unsure/guessing/lost/help!)

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7. The solidification age ("radioactive dating") of a sample resets to zero after it has been melted and then cooled back to a solid, because the gaseous daughter elements:

(A) escape.
(B) decay.
(C) become inert material.
(D) become radioactive elements.
(E) (Unsure/guessing/lost/help!)

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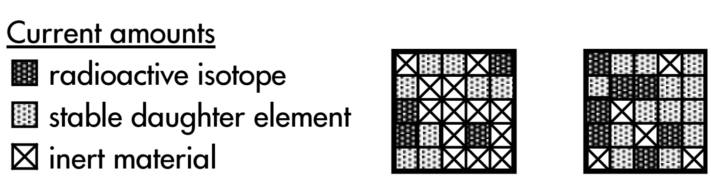
8. Two samples have certain amounts of a radioactive isotope, an embedded gaseous daughter element (which is the byproduct of the radioactive decay process), and inert material (which is not involved in the decay process).



(A) (B)

As determined by radioactive dating, sample __________ is older.

(A) (A).
(B) (B).
(C) (There is a tie.)
(D) (Cannot be determined.)

Five types of decay processes are listed below:

(A) α decay.
(B) β^- decay.
(C) β^+ decay.
(D) electron capture.
(E) γ decay.

9. Identify the process(es) (if any) that decrease the number of protons in the nucleus.

Decreasing proton process(es):

10. Identify the process(es) (if any) that decrease the number of neutrons in the nucleus.

Decreasing neutron process(es):

11. Identify the process(es) (if any) that convert a proton to a neutron in the nucleus.

Proton-to-neutron conversion process(es):

12. Identify the process(es) (if any) that convert a neutron to a proton in the nucleus.

Neutron-to-proton conversion process(es):

13. Identify the process(es) (if any) that do not change the number of protons and the number of neutrons in the nucleus.

Constant numbers of protons and neutrons process(es):

Different unstable isotopes of tellurium undergo different types of decay processes[1]. (The blank spaces are the important decay process particles; the presence of neutrally-charged neutrinos and antineutrinos are noted for completeness.)

(A) $^{106}_{52}\text{Te} \rightarrow {}^{102}_{50}\text{Sn} +$ _____.

(B) $^{107}_{52}\text{Te} \rightarrow {}^{103}_{50}\text{Sn} +$ _____.

(C) $^{117}_{52}\text{Te} \rightarrow {}^{117}_{51}\text{Sb} +$ ______ + (neutrino).

(D) $^{118}_{52}\text{Te} +$ _____ $\rightarrow {}^{118}_{51}\text{Sb}$ + (neutrino).

(E) $^{121}_{52}\text{Te} \rightarrow {}^{121}_{52}\text{Te} +$ ______.

(F) $^{123}_{52}\text{Te} +$ _____ $\rightarrow {}^{123}_{51}\text{Sb}$ + (neutrino).

(G) $^{127}_{52}\text{Te} \rightarrow {}^{127}_{53}\text{I} +$ ______ + (antineutrino).

14. Identify the process(es) (if any) that decrease the number of protons in the nucleus.

Decreasing proton process(es):

15. Identify the process(es) (if any) that decrease the number of neutrons in the nucleus.

Decreasing neutron process(es):

16. Identify the process(es) (if any) that convert a proton to a neutron in the nucleus.

Proton-to-neutron conversion process(es):

17. Identify the process(es) (if any) that convert a neutron to a proton in the nucleus.

Neutron-to-proton conversion process(es):

18. Identify the $\begin{bmatrix} \alpha \text{ decay} \\ \beta^{+} \text{ decay} \\ \beta^{-} \text{ decay} \\ \text{electron capture} \\ \gamma \text{ decay} \end{bmatrix}$ process(es).

[1] http://en.wikipedia.org/wiki/Isotopes_of_tellurium.

19. __________ is an α decay process.

(A) ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn}$.

(B) ${}^{18}_{9}\text{F} \rightarrow {}^{18}_{8}\text{O}$.

(C) (Both of the above choices.)

(D) (Neither of the above choices.)

(E) (Unsure/guessing/lost/help!)

20. __________ is a β^{-} decay process.

(A) ${}^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb}$.

(B) ${}^{215}_{83}\text{Bi} \rightarrow {}^{215}_{84}\text{Po}$.

(C) (Both of the above choices.)

(D) (Neither of the above choices.)

(E) (Unsure/guessing/lost/help!)

21. __________ is a β^{+} decay process.

(A) ${}^{13}_{7}\text{N} \rightarrow {}^{13}_{6}\text{C}$.

(B) ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca}$.

(C) (Both of the above choices.)

(D) (Neither of the above choices.)

(E) (Unsure/guessing/lost/help!)

22. The __________ process(es) decreases the number of $\begin{bmatrix}\text{neutrons}\\ \text{protons}\end{bmatrix}$ in a nucleus.

23. The __________ process(es) $\begin{bmatrix}\text{emits a photon}\\ \text{turns a neutron into a proton}\\ \text{turns a proton into a neutron}\\ \text{emits a helium nucleus}\end{bmatrix}$.

(A) α.
(B) β^{-}.
(C) β^{+}.
(D) electron capture.
(E) γ.
(F) (More than one of the above choices.)
(G) (None of the above choices.)
(H) (Unsure/guessing/lost/help!)

Feynman diagram vertices are shown below. (Not all are valid.)

24. Cross-out ("×") invalid vertices.

25. Draw a solid circle around vertices where an electron emits a photon.

26. Draw a dashed circle around vertices where an electron absorbs a photon.

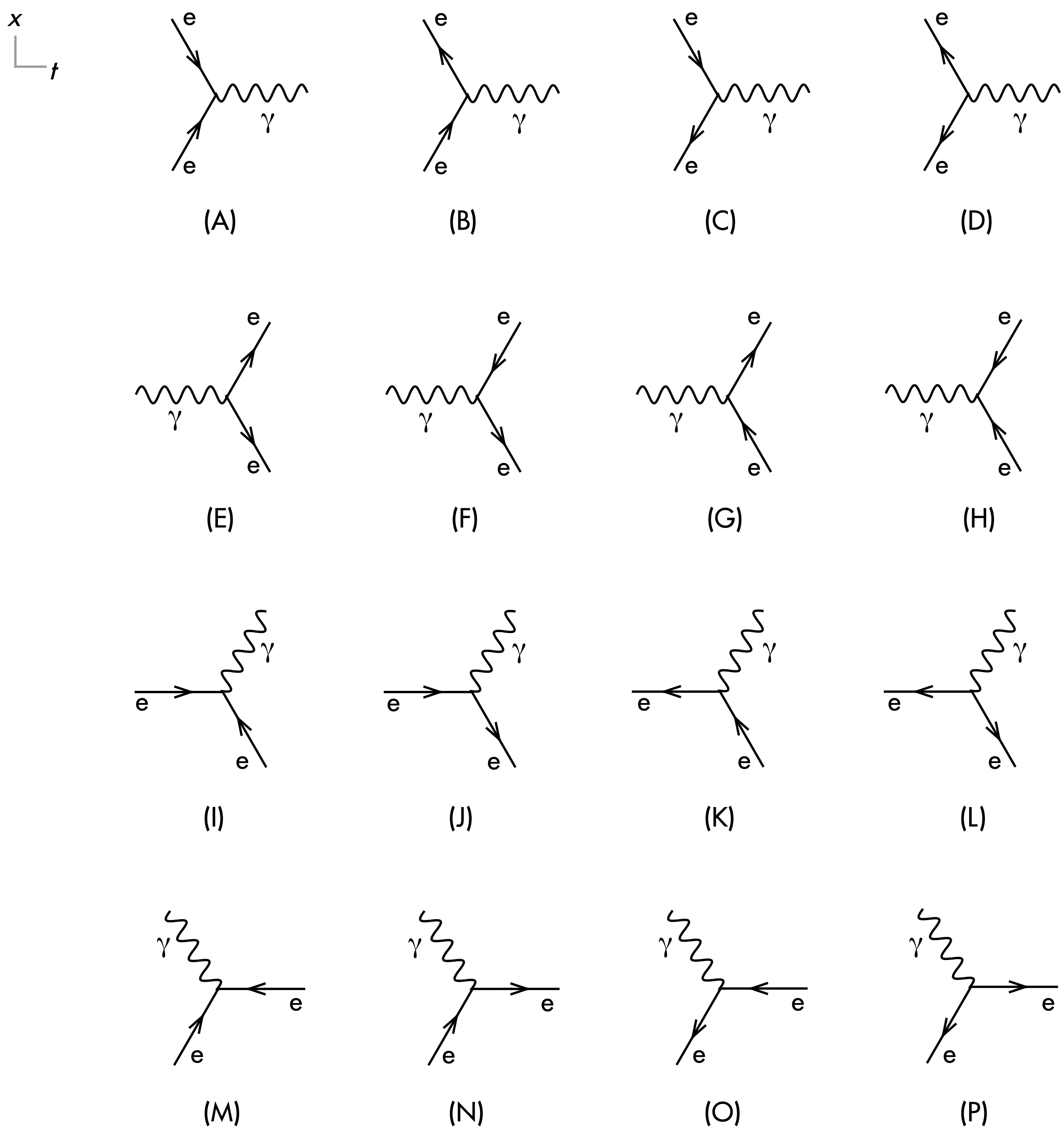
27. Draw a solid square around vertices where a positron emits a photon.

28. Draw a dashed square around vertices where a positron absorbs a photon.

29. Label "pair production" vertices where energy → matter + antimatter.

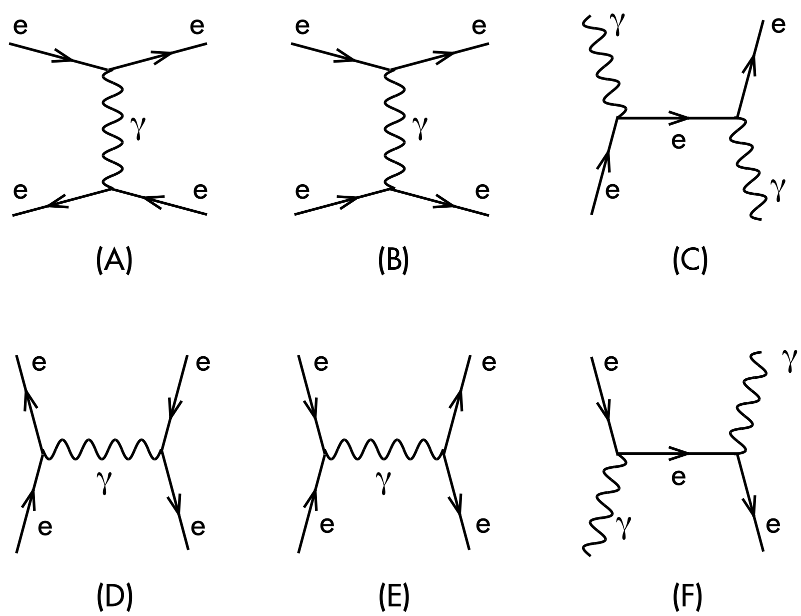
30. Label "annihilation" vertices where matter + antimatter → energy.

Solid lines: electrons/positrons (e).
Wavy lines: photons (γ).



Quantum electrodynamics (QED) Feynman diagrams are shown below. (Not all are valid.)

Solid lines: electrons/positrons (e).
Wavy lines: photons (γ).



31. Identify the diagram(s) (if any) that are invalid.

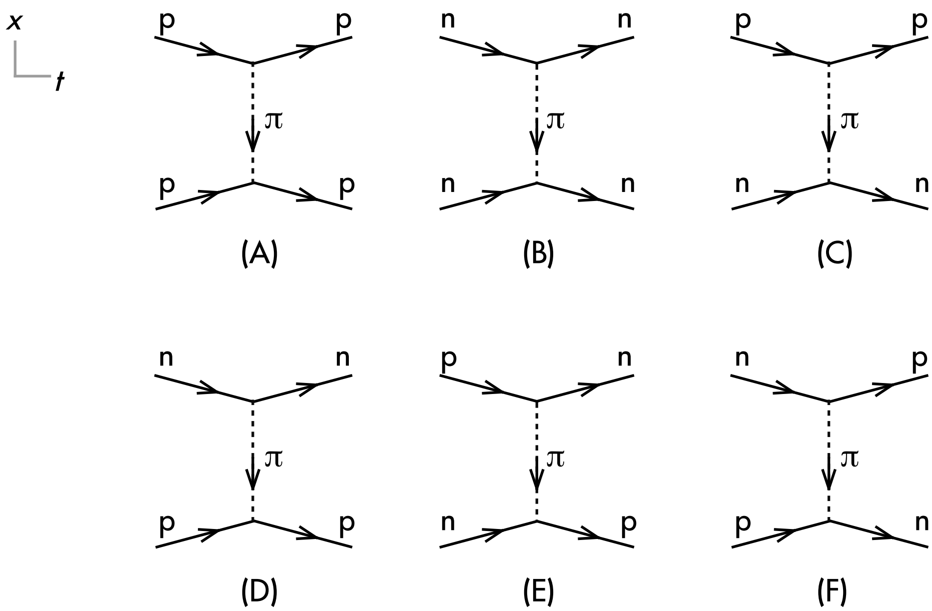
Invalid diagram(s):

32. Identify the diagram(s) (if any) for $\left[\begin{array}{l}\text{electron - electron repulsion}\\ \text{electron - positron attraction}\\ \text{electron - photon ("Compton") scattering}\\ \text{pair production (energy} \rightarrow \text{matter} + \text{antimatter)}\\ \text{annihilation (matter} + \text{antimatter} \rightarrow \text{energy)}\end{array}\right]$.

33. Identify the diagram(s) (if any) with a virtual photon interaction.

Valid "strong force" Feynman diagrams are shown below.

Solid lines: protons (p), neutrons (n).
Dashed lines: π^0, $\pi^\pm$ mesons ("pions").

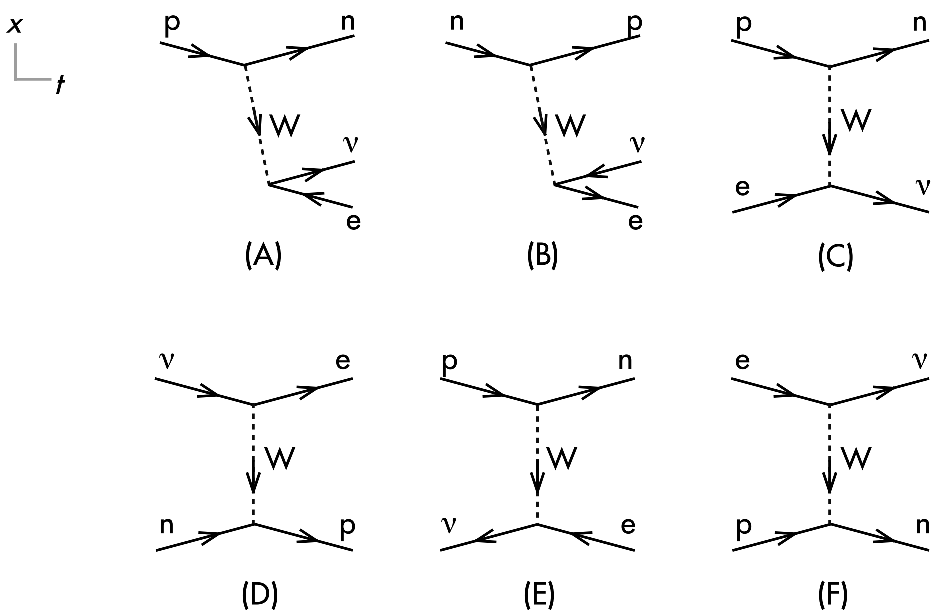


34. Identify the diagram(s) (if any) for $\begin{bmatrix} \text{proton - proton} \\ \text{neutron - neutron} \\ \text{proton - neutron} \end{bmatrix}$ attraction.

35. Identify the diagram(s) (if any) with a virtual $\begin{bmatrix} \text{neutral } (\pi^0) \\ \text{positive } (\pi^+) \\ \text{negative } (\pi^-) \end{bmatrix}$ interaction.

Valid "weak force" Feynman diagrams are shown below.

Solid lines: protons (p), neutrons (n), electrons/positrons (e), neutrinos/antineutrinos (ν).
Dashed lines: $W^{\pm}$ intermediate vector bosons.



36. Identify the diagram(s) (if any) for $\begin{bmatrix} \beta^+ \text{ decay} \\ \beta^- \text{ decay} \\ \text{electron capture} \end{bmatrix}$.

37. Identify the diagram(s) (if any) with a $\begin{bmatrix} \text{proton} \\ \text{neutron} \\ \text{electron} \\ \text{positron} \\ \text{neutrino} \\ \text{antineutrino} \end{bmatrix} \begin{bmatrix} \text{entering} \\ \text{leaving} \end{bmatrix}$ an interaction event.

38. Identify the diagram(s) (if any) with a virtual $\begin{bmatrix} \text{positive } (W^+) \\ \text{negative } (W^-) \end{bmatrix}$ interaction.

Equations and constants:

$$A = Z + N;\quad R(t) = R_0 e^{-\lambda t};\quad R(t) = R_0 \left(\frac{1}{2}\right)^{\left(\frac{t}{T_{1/2}}\right)};\quad T_{1/2} = \frac{\ln(2)}{\lambda};\quad \ln\left(e^x\right) = x;\quad \ln\left[\left(\frac{1}{2}\right)^x\right] = x \ln\left(\frac{1}{2}\right).$$