1. The **gravitational force** is the fundamental force that exists between A) any objects that have mass.

2. The **electrostatic force** is the fundamental force that exists between B) any objects that have charge.

3. The **strong nuclear force** is the fundamental force that exists between C) the protons and neutrons in an atomic nucleus.

4. Compare the behavior of each of these forces with increasing distance. The strength of D) all decreases, but the nuclear force decreases with distance much more rapidly than the other two.

5. Why is the strong nuclear force considered **fundamental**? B) It has properties that it does not share with either the gravitational or electrostatic force. These unique properties are necessary to explain how the neutrons are able to bind protons in the nucleus.

6. What are the properties of the strong nuclear force? B) It must attract nuclear particles very strongly over very short distances, but outside the nucleus, the strength drops rapidly off to zero.

7. The strong nuclear force acts over distances of about A) $10^{-14}$m, about the size of an atomic nucleus.

8. If the range of the strong force was **increased** slightly, B) there would be more elements because larger nuclei would be able to form and be stable.

9. Why are nuclear energies so large? C) Quantum mechanics and relativity combine to show that if the particle positions are well-defined, their speeds are very large and very uncertain, giving them high energy.

10. The structure of an atomic nucleus A) can be changed in a nuclear reaction.

11. Which of the following is **not** an example of a nuclear reaction? D) Oxidation: iron atoms exposed to water vapor combine with oxygen to form a reddish compound.

12. What is the difference between an **isotope** and an **ion**? B) An isotope is created when neutrons are added or removed from a nucleus.

13. The isotope carbon-13 can be written $^{13}_6$C. This means that it has C) 6 protons and 7 neutrons.

14. Compare the **mass** and **charge** of carbon isotopes $^{12}_6$C and $^{14}_6$C. B) Both should be neutral, but the $^{14}_6$C should be more massive by two neutrons.

15. Henri Becquerel discovered C) that photographic film exposed to uranium salts became fogged, indicating that the uranium was emitting some previously undetected ray.

16. **Alpha decay** occurs when a nucleus spontaneously emits A) a particle having two protons and two neutrons, along with a neutrino.

17. After an alpha decay, the **daughter nucleus** has D) two less protons than the parent nucleus.

18. Radon (Rn) is an **alpha emitter**. After $^{222}_{86}$Rn undergoes a single decay, the result is B) $^{218}_{84}$Po

19. **Beta decay** occurs when a nucleus spontaneously emits B) an electron, after a neutron converts itself into a proton plus an electron.

20. After a beta decay, the **daughter nucleus** has B) one more proton than the parent nucleus.
21. Iodine is a beta emitter. After $^{131}\text{I}$ undergoes a single decay, the result is
D) $^{54}\text{Ra}$

22. Which of the following nuclei is inherently unstable?
D) Astatine (At).

23. Why?
C) All nuclei with atomic number greater than 83 are unstable. As the nucleus gets larger, the short-range strong force begins to be overpowered by the long-range electrostatic repulsion.

24. Why are there only 118 elements on the periodic table?
B) Because there is an upper limit to how many protons you can have in a nucleus. Eventually the nucleus gets too big for the strong force to keep it bound together.

25. You flip a coin 10 times. At the same time, each of your three lab partners flips their coin also.
D) Any of the above results are possible, but not very likely. The most likely result is that, even if you flipped more heads than tails, someone else flipped more tails than heads. No one may have flipped exactly five of each, but the average number of heads for your group is probably pretty close to five.

26. Why?
A) Because according to the laws of probability, if there are only two possible outcomes for a random event, then either outcome is equally likely. You have a 50% chance of flipping heads, but you can’t predict in advance which flip will fall heads.

27. What does this have to do with radioactive decay?
B) Decay is a random event; the laws of probability govern. You cannot predict in advance which nucleus will decay or exactly when.

28. Define the idea of a half-life.
B) The time it takes for half of the isotopes in a sample to decay. If we use our radon sample above, we don’t actually care what happens after it becomes polonium. After one half life, half of the radon has decayed. After a second half-life, half of the remaining radon will have decayed. We continue to measure the decay of the radon that remains, not the polonium that has been created.

29. You have a sample of strontium isotopes ($^{90}\text{Sr}$). The half life is 30 years, and the original sample contained 2000 undecayed isotopes. After 90 years, there are how many remaining undecayed isotopes?
D) 250.

30. How many total years will it take before there are only about 62 undecayed isotopes left?
D) 150.

31. Why can’t you use carbon dating to determine the age of non–biological specimens?
B) Specimens that do not have a biological origin won’t have processed carbon, so you have no way to know what abundance of $^{14}\text{C}$ would have been present at the creation of the sample.

32. Compare the penetrating ability of alpha vs. beta radiation.
C) A sweatshirt would be sufficient to stop either; but if bare skin is exposed, an alpha particle would barely penetrate, while the beta would penetrate to a depth of about a centimeter.

33. Why are gamma rays ionizing, but radio waves are not?
C) High energy gamma rays can knock electrons off individual atoms in a cell, creating ions.

34. What is the largest source of radiation to which a typical person is exposed?
C) Radon.

35. When a neutron and proton fuse to become a hydrogen nucleus
C) nuclear energy is transformed into radiation and thermal energy.

36. Why are fusion reactions referred to as thermonuclear?
B) In any fusion reaction, you must have some external source of heat to start the reaction. Heat is also produced during the reaction, so there is thermal energy in and thermal energy out.
37. Why is thermal energy required to start a fusion reaction?
A) Because of electrostatic repulsion, it is hard to get nuclei close enough for the strong force to take over and fuse them. Heat makes the nuclei move faster, which permits them to get closer.

38. When \(^1\text{H}\) and \(^2\text{H}\) fuse to become \(^3\text{He}\), the resulting helium nucleus has slightly less mass than the two hydrogen nuclei from which it formed. How is this possible?
B) According to Einstein, \(E=mc^2\). This means that mass and energy are actually equivalent, and matter can be turned into energy. If you balance the books, you will see that energy conservation is not violated here, and a tiny amount of the matter has been converted to energy.

39. Why does fusion take place in the interior of stars?
C) The interior of a star is about the only place where you will find sufficiently high temperatures and pressures to start and maintain fusion reactions.

40. Two copper (Cu) nuclei spontaneously fuse together to form a cerium (Ce) nucleus. True or false?
A) False; copper nuclei will never be able to fuse spontaneously. They are too heavy.

41. Where does the iron in your blood come from?
D) A supernova explosion. Hey, it’s no more ridiculous than answers A through C, and has the advantage of being related to this whole fusion thing we have been discussing.

42. Related how?
B) Close; not quite right. Stars fuse elements up to iron. A massive star will then explode, and the resulting supernova actually provides the temperatures and pressures to fuse heavier elements than iron.

43. The first artificial radioactive isotopes were created by
A) Irène and Frédéric Joliot, in 1933. They created an isotope of phosphorous.

44. When \(^{13}\text{Al}\) is bombarded with alpha particles, one aluminum nucleus will absorb one alpha particle, and eject one neutron. The resulting isotope will be
D) \(^{15}\text{P}\)

45. Who is credited with the discovery of the neutron?
C) James Chadwick, 1932. He showed that certain emitted particles were uncharged, and could therefore not be protons or alpha particles.

46. Lise Meitner
C) performed crucial theoretical work confirming fission, but received no Nobel acknowledgement.

47. How does a fission reaction occur?
C) A nucleus splits apart. This is different from alpha decay because it will not happen spontaneously. Typically, it will occur when a nucleus is bombarded with energetic neutrons that disrupt the stability and permit the electrostatic repulsions to push large fragments apart.

48. Explain the concept of a chain reaction.
A) When a nucleus splits, an ejected neutron collides with a second nucleus. This causes the second nucleus to split, and it ejects a neutron. The result is a cascade of nuclear fission as more neutrons are ejected and collide with more nuclei.

49. The heaviest naturally occurring element is
C) \(92\), Uranium.

50. What is the difference between \(^{238}\text{U}\) and \(^{235}\text{U}\)?
C) \(^{238}\text{U}\) is common and stable, but \(^{235}\text{U}\) is rare and highly fissionable. Both occur naturally.