AP Physics Multiple Choice Practice – Modern Physics – ANSWERS

SECTION A – Quantum Physics and Atom Models

	Solution	Answer
1.	Standard photoelectric effect question. If the frequency does not cause emission, it is below the threshold and will not be able to cause emission. The only way to cause emission is the increase the frequency above the threshold.	B
2.	E=hf. Energy is directly related to frequency. The higher frequency means more energy.	C
3.	de Broglie wavelength is given by, $p = h / \lambda$ … $mv = h / \lambda$ … $\lambda = h / mv$ … 3x m = 1/3 λ.	B
4.	From $K = hf - \phi$ … $y = mx + b$ … the work function is the y intercept, extend the line.	A
5.	4–3,3–2,2–1 … or 4–2, 2–1 … or 4–3, 3–1 … or 4–1 … this is a total of 6 different transitions.	B
6.	While Rutherford's experiment did show most of these, looking at the single fact provided (that most particles pass straight through) only meant that most of the atom was empty space and that the nucleus must be small.	D
7.	Diffraction is a unique wave effect.	E
8.	Stopping potential is given by. $K=V_{stop}q$ ... combined with $K = hf - \phi$, we see the stopping potential is related to the incoming light energy minus the work function. However, none of the choices give a proper result. The answer depends on what that actual incoming energy hf and work function are. Here is an example. Lets say hf was 3eV and the ϕ was 2 eV initially. From $Vq=hf-\phi$ … the stopping potential for an electron (1e) would be equal to 1eV. Now if we were to half the work function, the new stopping potential would be 3eV – 1eV = 2 eV so it appears that the stopping potential doubled. But that result only works for those sample numbers. Lets assume instead that hf = 10eV and ϕ = 2eV. Now initially the V_{stop} = 8eV. Then we again half the work function … 10eV – 1 eV and we get a stopping potential of 9V .. not nearly doubled this time. The results depend on the actual numbers used because of the minus sign in the equation and not a simple multiplier effect.	E
9.	To transition to the $-12eV$ state with only two photon emissions, the only options are for the electron to make the following transitions: $-1eV \rightarrow -3eV \rightarrow -12eV$ giving us photons of energy $2eV$ and $9eV$ or $-1eV \rightarrow -7\ eV \rightarrow -12eV$ giving photons of energy $6eV$ and $5eV$. This means that the 4 eV photon is not possible with only two transitions.	B
10.	$K = hf - \phi$ … now double hf … $K_{new} = 2hf - \phi$ … (now sub in the first equation rearranged for hf, into the second equation) … $K_{new} = 2(K+\phi) - \phi = 2K + 2\phi - \phi$ … $K_{new} = 2K + \phi$ So the new energy is increased by double the old energy + the work function value.	E
11.	$p = h / \lambda$ … $mv = h / \lambda$ … $\lambda = h / mv = (6.63 \times 10^{-34}) / (9.11 \times 10^{-31})(1.6 \times 10^{7}) = 4.5 \times 10^{-11}$ m	C
12.	From above $\lambda = h / mv$ … Since $K = \frac{1}{2} mv^2$, 2x K means √2x v. So when we plug in the new velocity of √2v, the wavelength decreases by this factor since we divide.	A
13.	3 to 1 would be a higher energy emission. More energy means more frequency, and less λ but these are not choices. From $p = h / \lambda$, less λ means more momentum.	E

14. From $E = hf$, more frequency = more energy. D

15. Below a threshold frequency, there would be no emissions and thus zero K for everything below that point. Above that threshold, more frequency means more K based on $K = hf - \phi$, with h as the constant slope. Graph A has all these properties. A

16. Intensity has no effect on the energy of a single given photoelectron. Each photoelectron's energy is simply based on $K = hf - \phi$. More intensity means a larger total number of photoelectrons and would result in more total energy, but the energy of each photoelectron is the same for all levels of the overall intensity. E

17. The following formulas apply. $K = Vq$ … $K = \frac{1}{2} mv^2$ … $p = mv$ … $p=h/\lambda$ D

To get half the λ, the p must be doubled …
To double the momentum, the velocity must be doubled …
When the velocity is doubled, the Kinetic energy is 4x as much …
To get 4x the K, we need 4x the potential.

18. According to classical physics, when charges accelerate in circles, they necessarily radiate energy in the form of light. This would cause them to spiral into the nucleus as they radiate continuous spectrums of color. This does not happen though, which is a flaw in the Rutherford model. C

19. The ground state is at –14eV. The next excited state is 4eV higher (at –10eV) which cant be reached since we are only putting in a range of 7–10. So we try the next jump to the – 5eV state. This would require and input of 9 eV and this is possible since it falls in the range. The next state –3eV is not possible since it would require 11 eV input. So the only excited state we can be brought to with this energy input is the – 5eV state. From this state we will now go through emissions as the electrons fall back down to the ground state. This can be done through three possible jumps: B

–5eV→–10eV, then –10eV→–14eV or it could go directly from –5eV→–14eV.
In these three scenarios, the emissions possible are 5, 4 and 9.

20. X–rays do not have a charge so would not be deflected by a magnetic field. All of the rest of the listed properties are true however. a) x rays clearly pass through light materials as evidenced from their use in the medical field. b) From Bohr's energy level diagram for hydrogren we can conclude this is true. The differences between levels on the diagram represent energies needed to jump levels, and these energies correspond to visible and UV light energies. The energy listed for each level is the ionization energy, which is the energy needed to remove an electron. Any energy larger than or equal to the ionization energy for a level will do. Since X–rays have such high energy, they clearly will be able to ionize any level in hydrogen gas c) not true. d) The Compton effect shows this ability to strip electrons. e) An x ray is an EM wave and like all waves should diffract. Since the wavelength is so small, they would have to be diffracted by very small openings such as crystal structures in atoms. C

21. From $p=h/\lambda$, they are inverses. D

22. A) Not true. When particles came near the nucleus, most of them were deflected up or down through angles less than 90. A few of them, were deflected back at angles larger than 90. B

B) TRUE – Previous models could not accounts for the particles that got scattered through large angles. These large angle scattering events prompted Rutherford to conclude a concentrated + nucleus to produce this result.

23. Electron jumps could happen as follows 4–3,3–2,2–1 … or 4–2, 2–1 … or 4–3, 3–1 … or 4–1. In these emissions from the differences in the energy level graph, we can make all of the energy difference choices except 4 eV. D

24. Big λ means the least energy based on $E=hc/\lambda$. The least energy corresponds to the smallest energy level jump which is 4–3. E

25. The photoelectric effect is the main proof of lights particle nature. All of the other choices are related to the proof of wave natures. C

26. The Davisson–Germer experiment involves the diffraction of electron particles through a nickel crystal. Since these particles diffracted, this demonstrated the wave nature of particles. C

27. This is explained in question 16. K is based on the work function (which is based on the nature of the surface) and K is also based on the frequency of the incoming light. D

28. The quantization of energy levels is from de Broglie and the relationship of momentum to wavelength through matter–waves. de Broglie theorized that electrons have wavelike properties and must exist in whole number multiples of wavelengths around an orbit to so they interfere constructively and do not get knocked out. A

29. An obscure fact. Since the emission of X–ray photons are high energy, they must involve transitions to the lower energy level states since those jumps deal with high energy differences between states. A

30. The Davission–Germer experiment is discussed in question 26. The other two choices have nothing to do with matter–waves. B

31. From $p=h/\lambda$, 2x p means ½ the wavelength. B

32. Rutherford's experiment was not a quantum concept; it was on the atomic level and led to a model of the atom. All of the other choices involve a quantization effect or particle nature of light which are quantum concepts. A

33. From $p=h/\lambda$, and $c=f\lambda$ … $p = hf/c$. There is a direct relationship between p and f. A

34. The K of each photoelectron is given by. $K = hf - \phi$. To reduce the energy of each photon, we need less f (which means more λ) for the incoming light. Since intensity is directly related to the number of photoelectrons emitted we want to increase the intensity. B

35. A fact. The Pauli exclusion principle involves the filling of orbitals by electrons and how many electrons fill each orbital. This is related to the quantum state of the electrons in each level. B

36. Same as question 15. A

37. The photoelectric current is directly related to the number of photoelectrons emitted; the more photoelectrons the more the current. Also, the # of photoelectrons is directly related to the intensity. This means that photoelectric current and intensity also have a direct relationship. When we are above the threshold frequency, 0 intensity would correspond to 0 current, but as intensity increases, the current increases proportionally. D

38. We find the total energy produced in 1 second and then use the energy of 1 photon to determine how many photons would be emitted. C

    Total energy = $W = Pt = 50000\ (1\ \text{sec}) = 50000\ \text{J} = 5\text{x}10^{4}$

    Energy of 1 photon $E = hc / \lambda = 2\text{x}10^{-25} / 4 = 0.5\text{x}10^{-25} = 5\text{x}10^{-26}$

    Total Energy / Energy of 1 photon = # photons released.
    $5\text{x}10^{4} / 5\text{x}10^{-26} = 10^{30}$

39. From the equation. $\phi = hf_o$ … $f = \phi/h$ A

40. Energy of a photon is related to frequency. The red light has a lower frequency and thus less energy per photon. Intensity is the total energy of the beam. To have the same intensity, there would need to be more of the lower energy red photons. E

41. The energy of the electrons is the kinetic energy given by $W = Vq = K$. Doubling the voltage doubles the energy of the electrons. The emitted x–ray energy coming from the electron energy is given by $E=hf$ and with double the energy there should be double the frequency. E

SECTION B – Nuclear Physics

	Solution	Answer
1.	1 u = 1.66×10^{-27} is 1/12 of carbon 12 and is approximately the same as a proton mass.	E
2.	For a positron to be emitted, the oxygen must have undergone beta+ decay, which is the opposite of beta$^-$ decay. In beta+ decay a proton turns into a neutron + the emitted beta particle. The mass number stays the same (P+N still the same), but the atomic number goes down by 1 since there is 1 less proton.	B
3.	An alpha particle is $^4He_2$ so reduce the atomic mass by 4 and the atomic number by 2.	A
4.	In beta$^-$ decay, a neutron turns into a proton. Atomic mass same, mass number +1.	E
5.	Equate E=hf to E=mc^2 … m = hf/c^2.	B
6.	For everything to add up properly, we need … $\frac{1}{0}$ which is a neutron.	D
7.	Same as above.	D
8.	Definition of alpha particle.	A
9.	Uranium split by a neutron is called fission.	A
10.	Merging together two elements (He usually being one of them) is called fusion.	B
11.	This is the definition of Beta$^-$ decay.	B
12.	The mass number has changed by 28, the atomic number has changed by 10. 7 alpha particles ($^4He_2$)*7 equates to a loss of 28 for atomic mass and 14 for atomic number. If only the alpha particles were emitted, 4 protons would be missing. Those protons must have come from the conversion of neutrons into protons which would happen with the release of 4 beta particles.	B
13.	To balance the nuclear reaction, the sum of the values across the "top" and across the "bottom" must match… That is, we have $4 + 9 = 12 + A \rightarrow A = 1$ and $2 + 4 = 6 + Z \rightarrow Z = 0$. This gives us a particle with 1 nucleon, but 0 protons. This is a neutron.	E
14.	Conservation of charge is required. Eliminating an electron by itself violates this. *However, when and electron (–) meets a positron (+) the matter and antimatter can annihilate to produce energy and the + and – charges can neutralize to conserve charge .. just as a side note.*	E
15.	Simply balances the numbers across the top and bottom arrives at choice E.	E
16.	This is the similar to problem 12. Beta particles do not change the atomic mass number since there is simply a conversion between nucleons, so the only way to reduce the mass number is by emitting alpha particles. The mass number goes down by 32 and each alpha particle reduces it by 4 so 8 alpha particles are needed. 8 alpha particles by themselves would also reduce the atomic # by 16, but it only ends up reduced by 10 so there are 6 protons needed. These 6 protons come from the beta decay where 6 neutrons turn into protons and release 6 beta particles.	D
17.	For everything to add up properly, we need … $\frac{1}{1}$ which is a proton.	A

18. Gamma emission is pure energy so no particles change. E

19. First in the alpha decay, the atomic mass goes down by 4 and the atomic number goes down by 2 leaving $^{214}X_{82}$ … then in the two beta decays, a neutron turns into a proton each time increasing the atomic number by two leaving … $^{214}X_{84}$. B

20. Simply make sure everything adds up to get the missing piece. A

21. $^{214}Pb_{82} \rightarrow X + {}^{0}e_{-1}$ … For everything to add up, we need $^{214}X_{83}$ E

22. In a nuclear reaction, the total mass before must be larger than the total mass after since some of the mass will be 'missing' afterwards (mass defect) in the form of released energy. C

23. In this reaction, two light elements are fusing together and producing a heavier element. This is fusion. E

24. The reaction is as follows $^{1}p_{1} + {}^{14}N_{7} \rightarrow {}^{11}C_{6} + X$ … to make it all add up X must be an alpha. D

25. We start with 2 neutrons and 1 proton. In beta decay with the emission of an electron, the process involves a neutron turning into a proton. The resulting nucleus would have 1 neutron and 2 protons. An atomic number of 2 is defined as He. It is $^{3}He_{2}$ which is an isotope of $^{4}He_{2}$. A

26. A beta particle, like all matter, can exhibit wave properties. Since the particle is so small, it can more readily show these wave properties than normal size matter. E

27. Using $E=mc^2$ with twice the mass since two particles are destroyed A
$= (2*9.1x10^{-31})(3x10^{8})^2 = 1.64x10^{-13}$ J … $2.63x10^{-13}$ J * (1 eV / $1.6x10^{-19}$ J) = $1.02x10^{6}$ eV.
This is the total energy released, and since there are two photons we split it in half.

28. To conserve momentum, the photons must move in opposite directions. E

29. For everything to add up properly, 3 neutrons are needed. B

30. I. is Not True, for the following reason: A
In fission, and U–235 nucleus is broken into fragments that make smaller elements + neutrons + energy. The fragments created are not always the same and there is a statistical probability of which fragments can be created. The reaction provided in this problem is the most probable but other elements can be formed such as the following U–235 fission reaction:
U-235 + n $\rightarrow$ Zr-94 + Te-139 + 3n + energy. There are actually many combinations of fragments that can be released. Small amounts of mass are missing as released energy but adding the whole numbers of the reaction will always balance the equation for a given reaction.
II. is TRUE. As explained above, as small amount of the mass will be missing in the form of energy after the reaction completes. This is necessary to produce the energy from the reaction.
III. is Not True. Again as explained in the first paragraph. There will be a small amount of mass missing but adding the whole numbers before and after will always result in the same numbers of particles for a fission reaction.

31. $F_g=Gmm/r^2$ … $F_e = kqq/r^2$ … The electric and gravitational forces are inverse squared as shown from the equations here. Nuclear is not. This is fact and we don't know why. It was one of Einstein's last puzzles and he considered it a great failure of his to not solve this. It is called grand unification theory that attempts to combine all of the four fundamental forces into one unified force. It is a hot topic in modern physics that is as of yet unsolved. C

32. This is the definition of an isotope. Same atomic number so same number of protons. Different numbers of neutrons make it an isotope. Also a baseball team on The Simpsons. A

33. Some reactions conserve all of these, others do not. Clearly the numbers of protons is not conserved as evidenced by beta decay. The “number” of nuclei is more often conserved but in some reactions such as annihilation the nuclei are disintegrated and converted into energy. This agrees with the law of conservation of matter and energy, but when looking at the total numbers of particles before and the total numbers of particles after, you would say that number is not conserved. Charge is a fundamental conservation law and it always conserved. Even in the annihilation example, the net charge before was zero and is zero after. A

34. $^{214}Pb_{82} \rightarrow {}^{0}B_{-1} + \gamma + ?$ … For everything to add up, the missing product is $^{214}X_{83}$ D

35. This is a fact about stable elements. Generally ‘light’ elements are stable and have equal or near equal numbers of protons and neutrons. Ex: $^{16}O_8$, $^{4}He_2$. However, even for light elements, isotopes where there are more neutrons than protons become unstable. Heavier elements on the periodic table are naturally unstable and decay into smaller stable elements. For example. $^{238}U_{92}$ is unstable and will undergo decay until is turns into stable lead. Clearly U-238 has a lot more neutrons that protons and this excess is a sign of instability. A

36. This is a mass defect question. The energy released in the reaction is equal the equivalence of the missing mass comparing the products and reactants. C

37. For everything to add up we need a helium nucleus (alpha particle). D

38. These are all true statements about binding energy. E