Practice questions for Ch. 8

1. When ignited, a uranium compound burns with a green flame. The wavelength of the light given off by this flame is greater than that of
   A) red light
   B) infrared light
   C) radio waves
   D) ultraviolet light
   E) yellow light

2. Which form of electromagnetic radiation has the longest wavelengths?
   A) gamma rays
   B) microwaves
   C) radio waves
   D) infrared radiation
   E) x-rays

3. Which of the following are incorrectly paired?
   A) wavelength – λ
   B) frequency – ν
   C) speed of light – c
   D) hertz – s^{-1}
   E) x-rays – shortest wavelength

4. Green light can have a wavelength of 543 nm. The energy of a photon of this light is
   A) 1.08×10^{-31} J
   B) 5.43×10^{-7} J
   C) 3.66×10^{-19} J
   D) 5.52×10^{14} J
   E) 2.73×10^{18} J

5. Consider an atom traveling at 1% of the speed of light. The de Broglie wavelength is found to be 1.46×10^{-3} pm. Which element is this?
   A) Be
   B) Zr
   C) Kr
   D) Fe
   E) P

From the following list of observations, choose the one that most clearly supports the following conclusion:

a) emission spectrum of hydrogen
b) the photoelectric effect
c) scattering of alpha particles by metal foil
d) diffraction
e) cathode "rays"

6. Electrons have wave properties.
   A) observation a
   B) observation b
   C) observation c
   D) observation d
   E) observation e

7. Electromagnetic radiation has wave characteristics.
   A) observation a
   B) observation b
   C) observation c
   D) observation d
   E) observation e

8. Electrons in atoms have quantized energies.
   A) observation a
   B) observation b
   C) observation c
   D) observation d
   E) observation e

9. Spacing between atoms in a crystal is on the same order as the de Broglie wavelength of accelerated electrons.
   A) observation a
   B) observation b
   C) observation c
   D) observation d
   E) observation e

10. In an investigation of the electronic absorption spectrum of a particular element, it is found that a photon having $\lambda = 500$ nm provides just enough energy to promote an electron from the second quantum level to the third. From this information, we can deduce
   A) the energy of the $n = 2$ level
   B) the energy of the $n = 3$ level
   C) the sum of the energies of $n = 2$ and $n = 3$
   D) the difference in energies between $n = 2$ and $n = 3$
   E) all of these

Consider the following portion of the energy-level diagram for hydrogen:

$n = 4$	-0.1361×10^{-18} J
$n = 3$	-0.2420×10^{-18} J
$n = 2$	-0.5445×10^{-18} J
$n = 1$	-2.178×10^{-18} J

11. For which of the following transitions does the light emitted have the longest wavelength?
   A) $n = 4$ to $n = 3$
   B) $n = 4$ to $n = 2$
   C) $n = 4$ to $n = 1$
   D) $n = 3$ to $n = 2$
   E) $n = 2$ to $n = 1$

12. When a hydrogen electron makes a transition from $n = 3$ to $n = 1$, which of the following statements is *true*?
   I. Energy is emitted.
   II. Energy is absorbed.
   III. The electron loses energy.
   IV. The electron gains energy.
   V. The electron cannot make this transition.

   A) I, IV
   B) I, III
   C) II, III
   D) II, IV
   E) V

13. When an electron in a 2*p* orbital of a particular atom makes a transition to the 2*s* orbital, a photon of approximate wavelength 629.1 nm is emitted. The energy difference between these 2*p* and 2*s* orbitals is

A) 3.16×10^{-28} J

B) 3.16×10^{-19} J

C) 3.16×10^{-17} J

D) 1.25×10^{-31} J

E) none of these

14. The energy of the light emitted when a hydrogen electron goes from $n = 2$ to $n = 1$ is what fraction of its ground-state ionization energy?

A) 3/4
B) 1/2
C) 1/4
D) 1/8
E) 1/9

16. Which of the following best describes an orbital?

A) space where electrons are unlikely to be found in an atom
B) space which may contain electrons, protons, and/or neutrons
C) the space in an atom where an electron is most likely to be found
D) small, walled spheres that contain electrons
E) a single space within an atom that contains all electrons of that atom

17. How many f orbitals have $n = 6$?

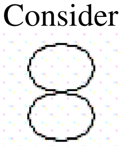
A) 2
B) 7
C) 10
D) 5
E) 18

18. If $n = 2$, how many orbitals are possible?
A) 3
B) 4
C) 2
D) 8
E) 6

19. Which of the following is an incorrect designation for an atomic orbital?
A) 1*s*
B) 3*d*
C) 1*p*
D) 4*f*
E) 6*s*

20. The number of orbitals having a given value of l is equal to
A) $2l + 1$
B) $2n + 2$
C) $3l$
D) $l + m_l$
E) the number of lobes in each orbital

21. Consider the following representation of a 2*p*-orbital:



Which of the following statements best describes the movement of electrons in a *p*-orbital?
A) The electrons move along the outer surface of the *p*-orbital, similar to a “figure 8” type of movement.
B) The electrons move within the two lobes of the *p*-orbital, but never beyond the outside surface of the orbital.
C) The electrons are concentrated at the center (node) of the two lobes.
D) The electrons are only moving in one lobe at any given time.
E) The electron movement cannot be exactly determined.

22. A point in the wave function where the amplitude is zero defines
A) the node
B) the excited state
C) the amplitude of the wave function
D) the frequency of radiation
E) none of the above

23. How many electrons can be described by the quantum numbers $n = 3$, $l = 3$, $m_l = 1$?
   A) 0
   B) 2
   C) 6
   D) 10
   E) 14

24. What is the l quantum number for a 4*s* orbital?
   A) 1
   B) 0
   C) 3
   D) 2
   E) more than one of the above

25. Which of the following combinations of quantum numbers (n, l, m_l, m_s) do *not* represent permissible solutions of the Schrödinger equation for the electron in the hydrogen atom (i.e., which combination of quantum numbers is *not* allowed)?
   A) 9, 8, -4, 1/2
   B) 8, 2, 2, 1/2
   C) 6, -5, -1, 1/2
   D) 6, 5, -5, 1/2
   E) All are allowed.

26. Which of the following combinations of quantum numbers is not allowed?
   A) $n = 1$, $l = 1$, $m_l = 0$, $m_s = {}^1\!/_2$
   B) $n = 3$, $l = 0$, $m_l = 0$, $m_s = -{}^1\!/_2$
   C) $n = 2$, $l = 1$, $m_l = -1$, $m_s = {}^1\!/_2$
   D) $n = 4$, $l = 3$, $m_l = -2$, $m_s = -{}^1\!/_2$
   E) $n = 4$, $l = 2$, $m_l = 0$, $m_s = {}^1\!/_2$

28. Mendeleev is given the most credit for the concept of a periodic table of the elements because:
   A) He had the longest history of research in elemental properties.
   B) He emphasized its usefulness in predicting the existence and properties of unknown elements.
   C) His representation of the table was the most understandable.
   D) His periodic table was arranged in octaves.
   E) He grouped elements into triads of similar properties.

29. Which of the following was not an elemental property usually predicted by Mendeleev for as-yet-unknown elements?
   A) electron configuration
   B) atomic mass
   C) density
   D) boiling point
   E) oxide formula

30. Which of the following atoms or ions has three unpaired electrons?
   A) N
   B) O
   C) Al
   D) S^{2-}
   E) Ti^{2+}

31. The electron configuration for the barium atom is:
   A) $1s^22s^22p^63s^23p^64s^23d^{10}$
   B) $[Xe]6s^2$
   C) $1s^22s^22p^63s^23p^64s^1$
   D) $1s^22s^22p^63s^23p^64s^2$
   E) none of these

32. The electron configuration for the carbon atom is:
   A) $1s^22s^22p^2$
   B) $[He]2s^4$
   C) $[Ne]2s^22p^2$
   D) $1s^22p^4$
   E) none of these

33. The complete electron configuration of tin is
  A) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5d^{10} 5p^2$
  B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4d^{10} 4p^2$
  C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^6 5s^2 4d^{10} 5d^{10} 5p^2$
  D) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^2$
  E) none of these

34. The statement that "the lowest energy configuration for an atom is the one having the maximum number of unpaired electrons allowed by the Pauli principle in a particular set of degenerate orbitals" is known as
  A) the aufbau principle
  B) Hund's rule
  C) Heisenberg uncertainty principle
  D) the Pauli exclusion principle
  E) the quantum model

36. An element with the electron configuration [Xe] $6s^2 4f^{14} 5d^7$ would belong to which class on the periodic table?
  A) transition elements
  B) alkaline earth elements
  C) halogens
  D) rare earth elements
  E) none of the above

37. All alkaline earths have the following number of valence electrons:
  A) 1
  B) 3
  C) 6
  D) 2
  E) none of these

38. Germanium has __________ in its 4p orbitals.
   A) one electron
   B) two electrons
   C) three electrons
   D) four electrons
   E) none of these

39. Fe has __________ that is (are) unpaired in its d orbitals.
   A) one electron
   B) two electrons
   C) three electrons
   D) four electrons
   E) none of these

Nitrogen has five valence electrons. Consider the following electron arrangements.

	2s	2p		
a)	↑↓	↑	↑	↑
b)	↑	↑↓	↑	↓
c)	↑	↑↑	↑	↑
d)	↑↓	↑	↑	
e)	↑↓	↑↓	↑	↑

40. Which represents the ground state for N?
   A) option a
   B) option b
   C) option c
   D) option d
   E) option e

41. Which represents the ground state for the N^- ion?
   A) option a
   B) option b
   C) option c
   D) option d
   E) option e

42. An atom of fluorine contains nine electrons. How many of these electrons are in *s* orbitals?
A) 2
B) 4
C) 6
D) 8
E) none

43. Of the following elements, which has occupied *d* orbitals in its ground-state neutral atoms?
A) Ba
B) Ca
C) Si
D) P
E) Cl

44. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$ is the correct electron configuration for which of the following atoms?
A) Ca
B) Ti
C) Ge
D) Zr
E) none of these

45. The number of unpaired electrons in the outer subshell of a Cl atom is
A) 0
B) 1
C) 2
D) 3
E) none of these

46. Which of the following electron configurations is different from that expected?
A) Ca
B) Sc
C) Ti
D) V
E) Cr

47. Which of the following is the highest energy orbital for a silicon atom?
A) 1*s*
B) 2*s*
C) 3*s*
D) 3*p*
E) 3*d*

True/False
Indicate whether the statement is true or false.

56. Diffraction results when light is scattered from a regular array of points or lines.

Short Answer

Given the following electronic configuration of neutral atoms, identify the element and state the number of unpaired electrons in its ground state:

57. $[Ar]4s^{1}3d^{5}$

58. $[Ne]3s^{2}3p^{5}$

Write the electron configuration for the following:

59. P

60. S^{2-}

61. K^{+}

Answer Section

MULTIPLE CHOICE

1. ANS: D

2. ANS: C

3. ANS: E

4. ANS: C

5. ANS: B

6. ANS: D

7. ANS: D

8. ANS: A

9. ANS: D

10. ANS: D

11. ANS: A

12. ANS: B

13. ANS: B

14. ANS: A

16. ANS: C

17. ANS: B

18. ANS: B

19. ANS: C

20. ANS: A

21. ANS: E

22. ANS: A

23. ANS: A

24. ANS: B

25. ANS: C

26. ANS: A

28. ANS: B

29. ANS: A

30. ANS: A

31. ANS: B

32. ANS: A

33. ANS: D

34. ANS: B

36. ANS: A

37. ANS: D

38. ANS: B

39. ANS: D

40. ANS: A

41. ANS: E

42. ANS: B

43. ANS: A

44. ANS: B

45. ANS: B

46. ANS: E

47. ANS: D

TRUE/FALSE

56. ANS: T

SHORT ANSWER

57. ANS:
The element is Cr with six unpaired electrons in its ground state.

58. ANS:
The element is Cl with one unpaired electron in its ground state.

59. ANS:
$1s^2 2s^2 2p^6 3s^2 3p^3$ or $[Ne]3s^2 3p^3$

60. ANS:
$1s^2 2s^2 2p^6 3s^2 3p^6$ or $[Ne]3s^2 3p^6$

61. ANS:
$1s^2 2s^2 2p^6 3s^2 3p^6$ or [Ar]

Answers to selected practice questions

(4) $\lambda = 543 \text{ nm} \times \dfrac{10^{-9} \text{ m}}{1 \text{ nm}} = 5.43 \times 10^{-7} \text{ m}$

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^{8} \text{ m/s}}{5.43 \times 10^{-7} \text{ m}} = 5.52 \times 10^{14} \text{ s}^{-1}$$

$$E_{photon} = \hbar\nu = (6.626 \times 10^{-34} \text{ J.s})(5.52 \times 10^{14} \text{ s}^{-1}) = 3.66 \times 10^{-19} \text{ J}$$

(5) $\lambda_{deBroglie} = \dfrac{\hbar}{mv}$

$$1.46 \times 10^{-3} \text{ pm} \times \frac{10^{-12} \text{ m}}{1 \text{ pm}} = \frac{6.626 \times 10^{-34} \frac{\text{kg} \cdot \text{m}}{\text{s}^2}}{m \; (0.01)(3.00 \times 10^{8} \frac{\text{m}}{\text{s}})}$$

$$\Rightarrow m = 1.51 \times 10^{-25} \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \underbrace{\frac{6.02 \times 10^{23} \text{ u}}{1 \text{ g}}} = 91.1 \text{ u}$$

Avogadro's no. is the conversion factor between grams and atomic mass units

91.1 matches **Zr**

(6) Diffraction is a fundamentally a wave property. Particles do not diffract when acting as particles. They diffract only when they act as waves.

(7) Diffraction is the tell-tale sign of a wave

(8) Emission spectrum of hydrogen comes from the light generated when an electron jumps from a higher level to a lower level. Since the spectrum is composed of discrete frequencies (as opposed to a continuous "rainbow" of frequencies like sunlight), it implies that the jumps can have only certain energy values, which in turn implies that the individual energy levels have only certain energy values.

(9) The way the question is phrased is a bit awkward, but OK. If the spacing between atoms in a crystal is comparable to the de Broglie wavelength of the electrons, they will act as waves and diffract. So the correct answer is "diffraction".

(10) Photons emitted or absorbed by an atom always correspond to a <u>difference</u> in energy levels. If the photon is promoting the electron from the 2nd quantum level to the 3rd, then its energy is equal to the difference in energies between $n=2$ and $n=3$

(11) Longest λ means lowest ν (and lowest energy)

Since $E_{photon} = \Delta E_{atom} \propto \left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2}\right)$

the lowest value would be obtained when n_{final} and $n_{initial}$ are closest, and among equally close (in this case a difference of 1), the largest n_{final} and $n_{initial}$ would have the smallest difference (i.e. $n=4$ to $n=3$)

Or one can simply calculate $\left(\frac{1}{n_{final}^2} - \frac{1}{n_{initial}^2}\right)$ for all the choices and find the smallest.

⟹ $n=4$ to $n=3$: $\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 0.049$

$n=4$ to $n=2$: $\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 0.188$

$n=4$ to $n=1$: $\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = 0.938$

$n=3$ to 2: $\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 0.139$

$n=2$ to 1: $\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = 0.75$

(12) When an electron makes a transition from $n=3$ to $n=1$, it loses energy, and that lost energy is emitted as a photon.

I and <u>III</u> are true.

(13) $\Delta E_{electron} = -E_{photon} = -(h\nu) = -\frac{hc}{\lambda} = -\frac{(6.626\times10^{-34}\,J.s)(3.00\times10^{8}\,m/s)}{629.1\times10^{-9}\,m}$

↑ because the photon is emitted
ΔE is negative (E_{photon} is always positive)

$\Delta E_{electron} = -3.16\times10^{-19}\,J$

The question simply asks for the "energy difference", so we skip the sign anyway. It's implicit in the context.

Energy difference $= 3.16\times10^{-19}\,J$

(14) Ionization energy $= -2.178\times10^{-18}\,J\left(\frac{1}{\infty}^{\nearrow 0} - \frac{1}{1^2}\right)$

$E_{photon} = -\Delta E_{n=2\to1} = +2.178\times10^{-18}\,J\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$\frac{E_{photon}}{\text{Ionization energy}} = \frac{\frac{3}{4}}{1} = \frac{3}{4}$

(17) This is an awkward way of asking "how many f-orbitals does the 6th shell have?". Number of f-orbitals in <u>any</u> shell that <u>can</u> have them is the <u>same</u>: 7

(18) For n=2, we can have s and p orbitals, for a total of
1 + 3 = 4 orbitals
(1 ← s, 3 ← p)

(19) 1p is wrong, because n=1 only allows an s-orbital

(20) Those orbitals would have m_ℓ values going from $-\ell$ to $+\ell$, including $m_\ell = 0$ ⟹ ℓ orbitals from the negative side
ℓ orbitals from the positive side
1 orbital from $m_\ell = 0$
⟹ $2\ell + 1$

(21) Orbitals have characteristic "shapes", in the sense of where the electron is likely to spend time. However, they don't have borders (any more than a fog has a border). Electrons are not confined to a surface or a curve. In the case of a p-orbital, they spend most of their time in the region containing most of the "probability density", and avoid the node between the two lobes. Since the electron is acting as a wave in the orbitals, it is delocalized over the entire orbital, not just one "lobe" or the other. The "movement" of the electron cannot be exactly determined.

(23) A trick question. ℓ can range from Ø to $n-1$. There is no $\ell = 3$ for $n = 3$ ($\ell = 2$ is the maximum)

(24) Any s-orbital has $\ell = Ø$

(25) ℓ cannot be negative, no the choice with $\ell = -5$ is not possible

(26) ℓ can only range from Ø to $n-1$, so $n = 1, \ell = 1$ is not possible

(30) For neutral atoms and anions, we need to consider only the last subshell that is being filled.
For cations, we need to consider the valence shell as well, if it's different from the shell that's currently being filled (as in transition metals)

N: ↑ ↑ ↑ (2p) ← 3 unpaired electrons

O: ↑↓ ↑ ↑ (2p)

Al: ↑ _ _ (3p)

S^{2-}: ↑↓ ↑↓ ↑↓ (3p)

Ti^{2+}: ↑↓ (4s — lost upon ionization) ↑ ↑ _ (3d)

(36) 5d subshell is incomplete, so it is a transition element

(39) Fe has a 4d orbital that is populated as follows:

↑↓ ↑ ↑ ↑ ↑

It has 4 unpaired electrons

(40) Ground state cannot have an orbital partially occupied while an orbital that comes after it is also occupied. This eliminates choices b. and c. N has five electrons in its valence shell, leaving 3 unpaired electrons in 3p.

1↓ (2s) 1 1 1 (2p)

(41) We just add one e^- to the ground state configuration of N

1↓ (2s) 1↓ 1 1 (2p)

(42) Fluorine has 2 electrons in 1s and 2 electrons in 2s, for a total of 4 electrons in s orbitals.

(43) The "ground-state" of an atom is the configuration obtained by applying the aufbau principle as usual, filling the orbitals in the order of increasing energy, as we move along the periodic table. Ca, Si, P, and Cl are placed before we encounter the d-block. We encounter the d-block and start putting electrons (and keep them there) in the 4th period, after filling the 4s orbitals. Ca is the heaviest atom without any d electrons. Elements coming after that have d-electrons, whether they happen to be in the d-block or not. Ba has full 3d and 4d subshells.

(46) Cu and Cr are the two exceptions that you are expected to remember

(47) The highest energy orbital is last one that accepts an electron when we build the electron configuration of the atom. Si is in the p-block of Period 3, so the highest energy orbitals are the 3p orbitals.

(55) Krypton 1s orbital is smaller than the helium 1s orbital because krypton's nuclear charge draws the electrons closer. The 2s, 2p, 3s, 3p, 4s, 3d, and 4p electrons are almost entirely outside of the 1s orbital (farther away from the nucleus) and offer no shielding of the extra protons that the Kr nucleus has (36 versus the 2 that He has). Thus the 1s orbital of Kr is attracted to a much larger effective nuclear charge, and is pulled in a lot closer to the nucleus, therefore it has a smaller size than a He 1s orbital.

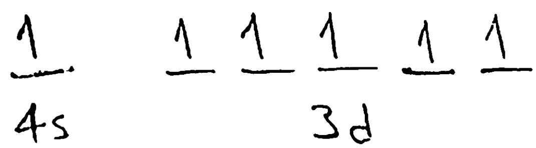
(56) A wave (light or other) diffracts (changes direction) when it encounters an obstacle next to an opening (such as a slit or a hole). Each slit or hole acts as if it's a source of the wave, and this results in interference patterns, if the distance between the openings is comparable to the wavelength of the wave. The statement "Diffraction results when light is scattered from a regular array of points or lines" is true.

(57) Cr and Cu are the exceptions that you are expected to know. They deviate from the expected electron configuration by "borrowing" an electron from the 4s orbital (leaving it half-filled) and achieving a half-filled 3d subshell (in the case of Cr) or a full 3d subshell (in the case of Cu). Half-filled or full subshells are favorable configurations.

$[Ar]4s^1 3d^5$ corresponds to Cr

It would also correspond to the Mn^+ ion, since the lost e^- would come from the valence shell. However, the question states that it is a neutral atom, so it is Cr.

To find the number of unpaired electrons, we construct the orbital diagram of the orbitals that come after [Ar]. ([Ar] configuration is composed of filled, paired orbitals)



Cr has 6 unpaired electrons in its ground state