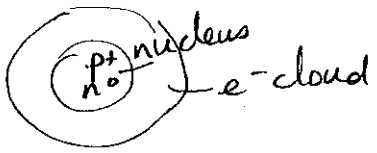
TOPIC 2 AND 3 PROBLEM SET – ATOMIC THEORY AND PERIODICITY

Atomic Theory

1. What is the atomic number? What information does it provide?
   — number of p^+ in nucleus of the atom.

2. What is the mass number? How is this different from (relative) atomic mass?
   $n^\circ + p^+$
   ↳ relative abundance of all isotopes of that element that exist in nature

3. According to the most current model of the atom, describe the location, charge, and relative mass of protons, neutrons and electrons. A labeled diagram may help.
   0 | 1 | 1



4. Define isotope.
   atoms of the same element w/ different mass # (change in # of neutrons)

5. Four elements are described below:

Element	# of protons	# of neutrons	# of electrons
A	5	6	2
B	1	1	1
C	1	0	0
D	5	5	5

   A) Which elements are isotopes of each other? (2 pairs) A + D and B + C

   B) How will elements A and D compare in terms of chemical/physical properties?

   C) How will elements A and D compare in terms of atomic mass? B is heavier

   D) How will elements B and C compare in terms of charge? C has +1 charge

   E) Draw atomic symbols for all four elements.
   A = $^{11}_{5}B^{+3}$ B = $^{2}_{1}H$ C = $^{1}_{1}H^{+1}$ D = $^{10}_{5}B$

6. Fill in the chart:

Isotope	# of protons	# of neutrons	# of electrons
$^{57}_{26}Fe$	26	31	26
$^{24}_{12}Mg^{+2}$	12	12	10
$^{14}_{6}C$	6	8	6
$^{12}_{6}C$	6	6	6
$^{235}_{92}U$	92	143	92
$^{35}_{17}Cl^{-1}$	17	18	18

7. Fill in the chart:

Atomic #	Symbol	# protons	Mass #	# neutrons	Charge	# electrons
33	As	33	75	42	-3	36
64	Gd	64	155	91	+3	61
12	Mg	12	25	13	+2	10
53	I	53	127	74	-1	54
48	Cd	48	115	67	0	48
58	Ce	58	140	82	+4	54
16	S	16	32	16	-2	18

8. Sketch a simple diagram of a mass spectrometer. Label each phase of the mass spectrometer's operation on the diagram.

Vaporized atoms are hit with high Energy e⁻ which knock out e⁻ in atoms producing + charged ions.

9. What specific piece of a mass spectrometer is adjusted in order to detect particles with varying masses?

10. Of the following particles, $^{16}O^{+}$, $^{15}O^{+}$, $^{16}O^{2+}$, $(^{16}O - ^{16}O)^{+}$ which experiences the greatest amount of deflection in a mass spectrometer? Why are all ions formed in a mass spectrometer positively charged?

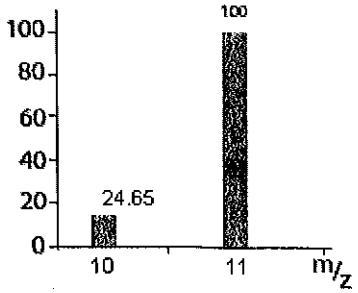
$\frac{m}{z} = \frac{\text{mass}}{\text{charge}}$ $^{16}O^{+} = \frac{16}{1} = 16$ $^{16}O^{2+} = \frac{16}{2} = 8$ → smallest has greatest deflection

$^{15}O^{+} = \frac{15}{1} = 15$ $(^{16}O - ^{16}O)^{1} = \frac{32}{1} = 32$

11. The following graph is produced when a pure sample of boron is passed through a mass spectrometer. Use the data to calculate the relative atomic mass for boron.

$(10 \times 24.65) + (11 \times 100) = \frac{1346.5}{124} = 10.86$

246.5 + 1100



12. Lithium occurs naturally as two isotopes, ^{6}Li and ^{7}Li. The relative atomic mass of lithium is 6.941 g/mol. Determine the percent abundance of each of lithium's isotopes.

$6x + 7(1-x) = 6.941$ → $6x + 7 - 7x = 6.94$ $-x = -0.059$

$x = 0.059 = 5.9\%$

$^{6}Li = 5.9\%$ $^{7}Li = 94.1\%$

13. State the name and the mass number of the isotope relative to which **all** atomic masses are measured.

Carbon-12

14. Write the symbol for the species with 17 protons, 19 neutrons, and 18 electrons.

$^{36}_{17}Cl^{-1}$

15. Write the symbol for the species with 6 protons, 8 neutrons, and 6 electrons.

$^{14}_{6}C$

16. Write the symbol for the species with 3 protons, 3 neutrons, and 2 electrons.

$^{6}_{3}Li^{+1}$

17. Explain why most atomic masses are not whole numbers.
- related to isotopes = ave abundance in nature

longer λ = lower E

18. In the context of electromagnetic radiation, what is wavelength? How does wavelength relate to energy?
distance between 2 corresponding pts. on successive waves (in m or nm)

19. In the context of electromagnetic radiation, what is frequency? How does frequency relate to energy? = f or ν
the # of waves that pass a point in space during any time interval (in s^{-1})

↑higher ν = higher E

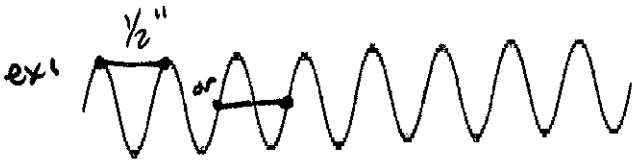
20. List the colors of visible light in order of increasing energy.
red, orange, yellow, green, blue, violet

21. a) Indicate the wavelength of each wave in the following wave diagrams.

b) Which of the waves has a higher frequency? B

c) Which of the waves has a lower energy? A

Wave A



Wave B

22. As wavelength gets shorter, frequency increases.

23. As wavelength gets shorter, energy increases

24. Describe the Bohr model of the atom, including the evidence collected that led to its development.
(describe planetary model)
- photon released when e⁻ falls to ground state
- E of photon ∝ to frequency of EM rad. going in
- photons can be quantized

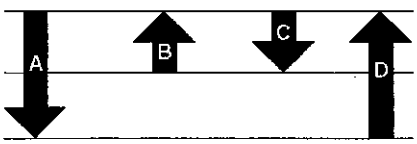
25. What is the difference between a bright line spectrum and a continuous spectrum? How do energy levels account for the appearance of bright line spectra?
"fingerprint" of element – only some E bands are visible

all visible E is seen 'continuously'

larger jumps = ↑energy bands (toward violet)

26. What is the electromagnetic (EM) spectrum? What is the highest energy wave? Lowest?
the range of all possible ν of electromag. radiation.
↳ gamma ↳ radio
visible: violet → red

27. Consider this diagram of an atom with arrows representing electron movement.



nucleus

a) Which two arrows correspond to energy absorption by the atom? B + D

b) Which two arrows correspond to energy emission by the atom? A + C

c) If violet and green light are produced by the movement illustrated here, which arrow represents emission of violet light? A green light? C

28. Consider the spectroscopy lab. How did the flame tests you performed on different metals relate to firework production? Why did each metal produce a different color flame when excited?

running voltage through a tube of the gas

29. Consider the spectroscopy lab. What caused the gas in the tubes to glow? How does this topic relate to "neon" sign production? Why is the term "neon sign" a bit misleading? neon are only specific red signs not other colors.

this is the same way neon signs are used to glow

31. How do scientists use bright line spectra to identify unknown elements in far off stars or other samples of matter?

each element has a unique bright line spectrum

32. Consider only the first four primary energy levels of a hydrogen atom. The transition that would result in photon of the **shortest** wavelength would be
(a) from n = 4 to n = 1 b) from n = 4 to n = 3
c) from n = 2 to n = 1 d) from n = 1 to n = 4

33. Consider only the first four primary energy levels of a hydrogen atom. The transition that would result in photon of the **longest** wavelength would be
a) from n = 4 to n = 1 (b) from n = 4 to n = 3
c) from n = 2 to n = 1 d) from n = 1 to n = 4

34. The Lyman series of bright lines in the hydrogen atom are due to electrons dropping to the first energy level, the Balmer series are due to electrons dropping to the second energy level. Which one of these series is U.V. and which is visible? Explain.

Lyman = U.V. larger drop = higher energy emission

35. How do waves of red light and blue light differ with respect to frequency? wavelength? energy?

red = longer λ, lower ν, lower E blue = shorter λ, higher ν, higher E

36. How many electrons can a single atomic orbital hold? How many orbitals can be found in an s sublevel? p? d? f?

1 orbital holds up to 2 e⁻ s = 1 orbital p = 3 orbitals d = 5 orbitals f = 7 orbitals

37. "s" sublevels can hold a total of 2 electrons. p sublevels can hold 6 electrons, while d sublevels can hold 10 and f sublevels can hold 14 electrons.

38. Which is bigger, the 3s sublevel or the 5s sublevel? How many electrons can each hold?

↳ 5s, both hold 2e⁻ each (up to 2)

39. What are valence electrons and why are they important? What is the octet rule? atoms tend to combine in a way as to have 8 e⁻ in its valence shell.

electrons in the outermost energy level/shell of an atom

40. Every element wants a full outer energy level (valence level). This is normally 8 electrons, although in the case of helium it is 2 electrons.

41. An atom is in the ground state when the electrons in an atom are in the lowest possible energy levels.

42. An atom is in the excited state when one or more electrons moves to a higher than normal energy level.

43. Which of the following has the highest energy?
A) 4d B) 5s (C) 5p D) 3p

44. Which of the following has the lowest energy?
A) 6s (B) 5p C) 4f D) 6p

45. Give electron complete configurations for: Na^+, Fe, Br, Ar, Al^{+3}, O^{-2}, He, Ni^{+2}, K, Ne, Cu^+.

Na^+: $1s^2\ 2s^2\ 2p^6$

Fe: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6 \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

Br: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$

Ar: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Al^{3+}: $1s^2\ 2s^2\ 2p^6$

O^{2-}: $1s^2\ 2s^2\ 2p^6$

He: $1s^2$

Ni^{+2}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$

K: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

Ne: $1s^2\ 2s^2\ 2p^6$

Cu^+: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

46. Give shorthand electron configurations for: Ag, I, Rb, Au, Cu, S^{-2}

Ag: $[Kr]\ 5s^1\ 4d^{10}$

I: $[Kr]\ 5s^2\ 4d^{10}\ 5p^5$

Rb: $[Kr]\ 5s^1$

Au: $[Xe]\ 6s^1\ 5d^{10}$

Cu: $[Ar]\ 3d^{10}\ 4s^1$

S^{2-}: $[Ne]\ 3s^2\ 3p^6$

47. What does isoelectronic mean? Give three elements that are isoelectronic with Kr.

having the same electron configuration (and therefore, the same # of electrons)

$Kr = Br^{1-} = Rb^{1+} = Sr^{2+}$

48. $1s^2 2s^2 2p^6 3s^2 3p^4$ is the electron configuration for which element? How many valence electrons does the element have? 4 valence electrons Sulfur

49. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$ is the electron configuration for which noble gas? How can you use its electron configuration to confirm it is a noble gas? Krypton

full 8e⁻ in 4th level = full valence shell

Periodicity

50. What is meant by effective nuclear charge?

51. Compare the effective nuclear charge on the valence electrons of sodium, magnesium and aluminum.

52. How can effective nuclear charge explain the observed difference in first ionization energy between sodium and magnesium? Consult table 7 of the data booklet for data regarding first ionization energies.

53. Despite the trend in effective nuclear charge, magnesium has a higher first ionization than aluminum. Explain this in terms of electron configuration.