

Topic: Atomic Structure

Concepts Outline

1. The modern model of the atom has evolved over a long period of time through the work of many scientists.

✓ *Dalton's Model:*

- Elements are made of atoms
- Atoms of an element are the same.
- Compounds are formed from combinations of atoms.

✓ *Rutherford Experiment*

- Bombarded gold foil with alpha particles. Showed atoms were mostly empty space with small, dense positively charged nucleus.

✓ *Bohr Model*

- Small, dense, positively charged nucleus surrounded by electrons in circular orbits.

✓ *Wave-Mechanical Model (Modern Atomic Theory)*

- Small, dense, nucleus positively charged nucleus surrounded by electrons moving in "electron cloud".
- "**Orbitals**" are areas where an electron with a certain amount of energy is *most likely* to be found.

2. Each atom is made of a positively charged nucleus with one or more orbiting, negatively charged electrons.

3. Protons and neutrons are found in the nucleus.

- ✓ The number of protons in an atom's nucleus gives the nucleus a positive charge. Li has a "nuclear charge" of +3, since it has 3 protons.

4. Protons have a positive charge, neutrons no charge, and electrons a negative charge.

5. The number of protons in an atom equals the number of electrons.

- ✓ The positive charges of the protons are cancelled by the negative charges of the electrons, so overall an *atom* has a neutral charge.

6. The mass of a proton is 1 amu. The mass of a neutron is 1 amu. The mass of an electron is almost 0 amu.

- ✓ The mass of an atom is contained in its nucleus.
- ✓ The atomic mass of an atom is equal to the total number of protons and neutrons.

7. Each electron in an atom has its own distinct amount of energy.

- ✓ When all electrons are at their lowest possible energy, it is called the "ground state."
- ✓ Electrons fill in energy levels and orbitals starting with the one that requires the least energy and progressively move to those levels and orbitals that require increasing amounts of energy.

- 8. When the electron gains a specific amount of energy, it moves to a higher orbital and is in the "excited state".**
- ✓ You can recognize an excited state electron configuration. If the configuration does not match that on the Periodic Table for that number of electrons, then it is an excited state.
- 9. When an electron returns from a higher energy state to a lower energy state, it emits a specific amount of energy usually in the form of light. This can be used to identify an element (bright line spectrum).**
- ✓ The instrument used to see the bright line spectrum is called a spectroscope.
- 10. The outermost electrons are called valence electrons. These affect the chemical properties of the element.**
- ✓ Atoms with a filled valence level are stable (noble gases).
 - ✓ Most elements can have up to 8 electrons in their valence level. The exceptions are H and He, which can have only 2 valence electrons.
 - ✓ Atoms form bonds in order to fill their valence levels.
 - ✓ You can use Lewis structures to show the configuration of the valence electrons.
- 11. Atoms of the same element all contain the same number of protons.**
- ✓ Changing the number of protons changes the atom into a different element.
 - ✓ The atomic number is the number of protons in an atom of an element.
- 12. Isotopes are atoms with equal numbers of protons but different numbers of neutrons.**
- ✓ Isotopes of an element have the same atomic number (protons only), but different atomic masses (protons + neutrons).
- 13. The average atomic mass of an element is the weighted average of its naturally occurring isotopes.**
- ✓ You need to know how to do the calculation of "weighted atomic mass" given isotope masses and percent abundances.
- 14. When an atom gains an electron, it becomes a negative ion and its radius increases.**
- 15. When an atom loses an electron, it becomes a positive ion and its radius decreases.**
- 16. Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. These values are based on an arbitrary scale.**
- ✓ Fluorine has the highest electronegativity of all elements (4.00).

Atomic Structure – Practice Questions

- Experiments performed to reveal the structure of atoms led scientists to conclude that an atom's
 - positive charge is evenly distributed throughout its volume
 - negative charge is mainly concentrated in its nucleus
 - mass is evenly distributed throughout its volume
 - volume is mainly unoccupied
- The modern model of the atom shows that electrons are
 - orbiting the nucleus in fixed paths
 - found in regions called orbitals
 - combined with neutrons in the nucleus
 - located in a solid sphere covering the nucleus
- An experiment in which alpha particles were used to bombard thin sheets of gold foil led to the conclusion that an atom is composed mostly of
 - empty space and has a small, negatively charged nucleus
 - empty space and has a small, positively charged nucleus
 - a large, dense, positively charged nucleus
 - a large, dense, negatively charged nucleus
- What is the atomic number of an element that has six protons and eight neutrons?
 - 6
 - 2
 - 8
 - 14
- An atom of fluorine has a mass of 19 atomic mass units. The total number of protons and neutrons in its nucleus is
 - 9
 - 10
 - 19
 - 28
- What is the total number of protons contained in the nucleus of a carbon-14 atom?
 - 6
 - 8
 - 12
 - 14
- What is the nuclear charge of an iron atom?
 - +26
 - +30
 - +56
 - +82
- Which of these elements has an atom with the most stable outer electron configuration?
 - Ne
 - Cl
 - Ca
 - Na
- How many electrons are in the outermost principal energy level of an atom of carbon in the ground state?
 - 6
 - 2
 - 3
 - 4
- Which electron configuration is correct for a sodium ion?
 - 2-7
 - 2-8
 - 2-8-1
 - 2-8-2
- What is the electron configuration of a sulfur atom in the ground state?
 - 2-4
 - 2-6
 - 2-8-4
 - 2-8-6

12. The nucleus of which atom contains 48 neutrons?

- (1) ${}_{16}^{32}\text{S}$ (2) ${}_{22}^{48}\text{Ti}$ (3) ${}_{37}^{85}\text{Rb}$ (4) ${}_{48}^{112}\text{Cd}$

13. The number of neutrons in the nucleus of an atom can be determined by

- (1) adding the atomic number to the mass number
(2) subtracting the atomic number from the mass number
(3) adding the mass number to the atomic mass
(4) subtracting the mass number from the atomic number

14. When an atom loses an electron, the atom becomes an ion that is

- (1) positively charged and gains a small amount of mass
(2) positively charged and loses a small amount of mass
(3) negatively charged and gains a small amount of mass
(4) negatively charged and loses a small amount of mass

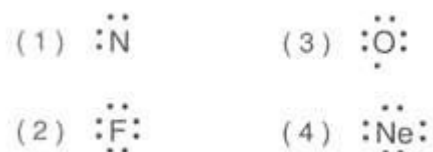
15. In which pair of elements do the nuclei of the atoms contain the same number of neutrons?

- (1) ${}^7\text{Li}$ and ${}^9\text{Be}$ (3) ${}^{23}\text{Na}$ and ${}^{24}\text{Mg}$
(2) ${}_{7}^{14}\text{N}$ and ${}_{8}^{16}\text{O}$ (4) ${}_{16}^{32}\text{S}$ and ${}_{17}^{35}\text{Cl}$

16. The characteristic spectral lines of elements are caused when electrons in an excited atom move from

- (1) lower to higher energy levels, releasing energy
(2) lower to higher energy levels, absorbing energy
(3) higher to lower energy levels, releasing energy
(4) higher to lower energy levels, absorbing energy

17. Which Lewis electron-dot structure is drawn correctly for the atom it represents?



18. When a lithium atom forms a Li^+ ion, the lithium atom

- (1) gains a proton (3) loses an electron
(2) loses a proton (4) gains an electron

19. What is the total number of electrons in the valence shell of an atom of aluminum in the ground state?

- (1) 8 (2) 2 (3) 3 (4) 10

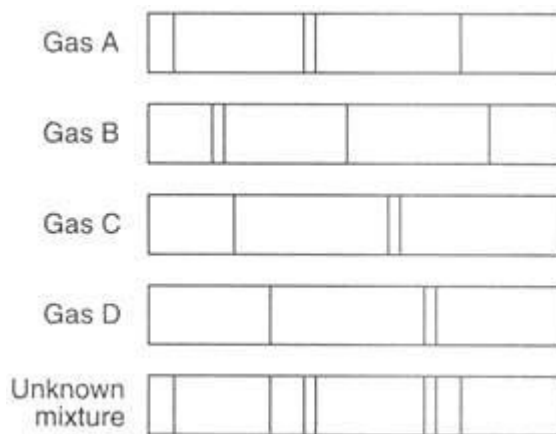
20. An electron in an atom moves from the ground state to an excited state when the energy of the electron

- (1) increases (2) decreases (3) remains the same

21. During a flame test, ions of a specific metal are heated in the flame of a gas burner. A characteristic color of light is emitted by these ions in the flame when the electrons
- (1) emit energy as they move to higher energy levels
 - (2) emit energy as they return to lower energy levels
 - (3) gain energy as they move to higher energy levels
 - (4) gain energy as they return to lower energy levels
22. What is the total number of electrons in a Cu^+ ion?
- (1) 36 (2) 29 (3) 30 (4) 28

Base your answers to questions 23 and 24 on the information and the bright-line spectra represented below.

Many advertising signs depend on the production of light emissions from gas-filled glass tubes that are subjected to a high-voltage source. When light emissions are passed through a spectroscope, bright-line spectra are produced.



23. Identify the two gases in the unknown mixture.
24. Explain the production of an emission spectrum in terms of the energy states of an electron.

Atomic Concepts – questions from previous Regents exams

1. Which subatomic particles are located in the nucleus of a neon atom?

- (1) electrons and positrons
- (2) electrons and neutrons
- (3) protons and neutrons
- (4) protons and electrons

2. The total mass of the protons in an atom of gold-198 is approximately

- (1) 79 atomic mass units
- (2) 119 atomic mass units
- (3) 198 atomic mass units
- (4) 277 atomic mass units

3. In a calcium atom in the ground state, the electrons that possess the *least* amount of energy are located in the

- (1) first electron shell
- (2) second electron shell
- (3) third electron shell
- (4) fourth electron shell

4. Which group of atomic models is listed in historical order from the earliest to the most recent?

- (1) hard-sphere model, wave-mechanical model, electron-shell model
- (2) hard-sphere model, electron-shell model, wave-mechanical model
- (3) electron-shell model, wave-mechanical model, hard-sphere model
- (4) electron-shell model, hard-sphere model, wave-mechanical model

5. Which isotopic notation represents an atom of carbon-14?

- (1) ${}^6_8\text{C}$
- (2) ${}^8_6\text{C}$
- (3) ${}^6_{14}\text{C}$
- (4) ${}^{14}_6\text{C}$

6. Which isotopic notation identifies a metalloid that is matched with the corresponding number of protons in each of its atoms?

- (1) ${}^{24}\text{Mg}$ and 12 protons
- (2) ${}^{28}\text{Si}$ and 14 protons
- (3) ${}^{75}\text{As}$ and 75 protons
- (4) ${}^{80}\text{Br}$ and 80 protons

7. According to the wave-mechanical model of the atom, electrons in an atom

- (1) travel in defined circles
- (2) are most likely found in an excited state
- (3) have a positive charge
- (4) are located in orbitals outside the nucleus

8. What is the total charge of the nucleus of a carbon atom?

- (1) -6
- (2) 0
- (3) +6
- (4) +12

9. A sample composed only of atoms having the same atomic number is classified as

- (1) a compound
- (2) a solution
- (3) an element
- (4) an isomer

10. Which two particles each have a mass approximately equal to one atomic mass unit?

- (1) electron and neutron
- (2) electron and positron
- (3) proton and electron
- (4) proton and neutron

11. Which electron configuration could represent a strontium atom in an excited state?

- (1) 2-8-18-7-1
- (2) 2-8-18-7-3
- (3) 2-8-18-8-1
- (4) 2-8-18-8-2

12. What is the total number of neutrons in an atom of ${}^{57}_{26}\text{Fe}$?

- (1) 26
- (2) 31
- (3) 57
- (4) 83

13. What is the total number of electrons in a Mg^{+2} ion?

- (1) 10 (3) 14
(2) 12 (4) 24

14. What was concluded about the structure of the atom as the result of the gold foil experiment?

- (1) A positively charged nucleus is surrounded by positively charged particles.
(2) A positively charged nucleus is surrounded by mostly empty space.
(3) A negatively charged nucleus is surrounded by positively charged particles.
(4) A negatively charged nucleus is surrounded by mostly empty space.

15. An atom is electrically neutral because the

- (1) number of protons equals the number of electrons
(2) number of protons equals the number of neutrons
(3) ratio of the number of neutrons to the number of electrons is 1:1
(4) ratio of the number of neutrons to the number of protons is 2:1

16. How do the energy and the most probable location of an electron in the third shell of an atom compare to the energy and the most probable location of an electron in the first shell of the same atom?

- (1) In the third shell, an electron has more energy and is closer to the nucleus.
(2) In the third shell, an electron has more energy and is farther from the nucleus.
(3) In the third shell, an electron has less energy and is closer to the nucleus.
(4) In the third shell, an electron has less energy and is farther from the nucleus.

17. What is the net charge on an ion that has 9 protons, 11 neutrons, and 10 electrons?

- (1) 1+ (3) 1-
(2) 2+ (4) 2-

18. Which value of an element is calculated using both the mass and the relative abundance of each of element?

- (1) atomic number (3) half-life
(2) atomic mass (4) molar volume

19. Which two notations represent different isotopes of the same element?

- (1) ${}^6_4\text{Be}$ and ${}^9_4\text{Be}$ (3) ${}^{14}_7\text{N}$ and ${}^{14}_6\text{C}$
(2) ${}^7_3\text{Li}$ and ${}^7_3\text{Li}$ (4) ${}^{32}_{15}\text{P}$ and ${}^{32}_{16}\text{S}$

Base your answers to questions 20 through 22 on the information below.

The accepted values for the atomic mass and percent natural abundance of each naturally occurring isotope of silicon are given in the data table below.

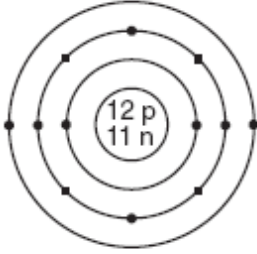
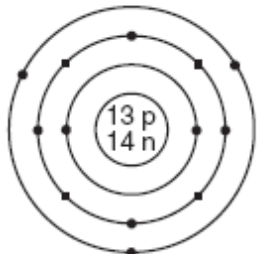
Naturally Occurring Isotopes of Silicon

Isotope	Atomic Mass (atomic mass units)	Percent Natural Abundance (%)
Si-28	27.98	92.22
Si-29	28.98	4.69
Si-30	29.97	3.09

20. Determine the total number of neutrons in an atom of Si-29. [1]
21. Show a correct numerical setup for calculating the atomic mass of Si. [1]
22. A scientist calculated the percent natural abundance of Si-30 in a sample to be 3.29%. Determine the percent error for this value. [1]
23. Write *one* electron configuration for an atom of silicon in an excited state.

Base your answers to questions 20 through 22 on the information below.

Atomic Diagrams of Magnesium and Aluminum

Key	Element	Lewis Electron-Dot Diagram	Electron-Shell Diagram
• = electron	magnesium	Mg:	
	aluminum	Al:	

24. Identify *one* piece of information shown in the electron-shell diagrams that is *not* shown in the Lewis electron-dot diagrams. [1]

25. Determine the mass number of the magnesium atom represented by the electron-shell diagram. [1]

26. Explain why Lewis electron-dot diagrams are generally more suitable than electron-shell diagrams for illustrating chemical bonding. [1]