

Because the central atom X obeys the octet rule, XY_2 must have linear geometry (and linear shape). With linear geometry, we have sp hybridization. We have 2 unhybridized p atomic orbitals with sp hybridization. Each unhybridized p atomic orbital will form a π bond. Because we have 2 unhybridized p atomic orbitals on the central X atom, X forms 2 π bonds.

1. The central atom in a molecule of the type XY_2 obeys the octet rule. Experiments show that the bond angle about the central atom X is 180° . How many π bonds does X form to the other atoms (Y) in this molecule?

- a. 0 (X forms no π bonds.)
- b. 1 π bond
- c. 2 π bonds
- d. 3 π bonds

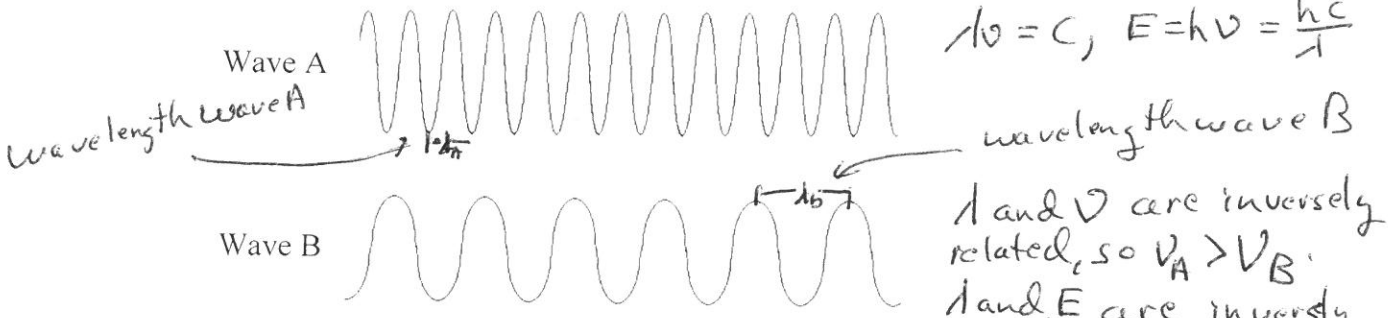
form a π bond. Because we have 2 unhybridized p atomic orbitals on the central X atom, X forms 2 π bonds

Examples:



2. Consider the figure below illustrating two different types of electromagnetic radiation.

Note that wavelength of wave B is longer than wavelength of wave A.



Which of the following statements (a-d) is **true** concerning wave A and wave B?

- F a. Wave A has a faster velocity than wave B. *both travel at speed of light (c)*
- F b. The wavelength of wave A is ^{shorter} longer than the wavelength of wave B.
- F c. The photon energy associated with wave A is ^{larger} smaller than the photon energy associated with wave B.
- F d. The frequency of wave A is ^{higher} lower than the frequency of wave B.
- e. None of these statements (a-d) are true.

Atom has tiny dense nucleus with electrons at relatively huge distances away from nucleus. Neutrons are neutral charge.

3. Which of the following is **true**?
- F a. All particles in the nucleus of an atom are charged.
 - F b. The atom is best described as a uniform sphere of matter in which electrons are embedded.
 - F c. The mass of the nucleus is only a very small fraction of the mass of the entire atom.
 - d. The volume of the nucleus is only a very small fraction of the volume of the entire atom.

F e. The number of neutrons in a neutral atom must equal the number of electrons.
of protons = # of electrons for a neutral atom

NO_3^- exhibits resonance (3 resonance structures are possible).
 Actual N-O bond length is between a single bond and a double bond, but closer to a single bond (average of the three resonance structures). This makes 1.67 units the correct choice. 1.50 units would be correct if only two resonance structures are possible (like in NO_2^-).

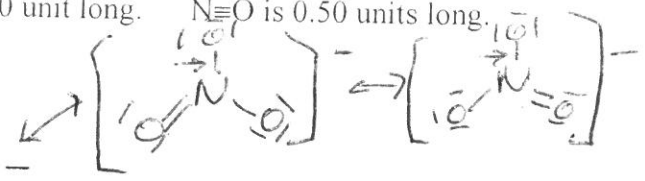
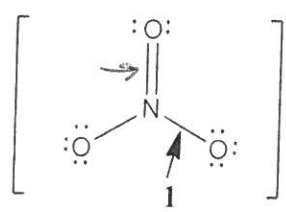
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4. Consider the following nitrogen-oxygen bond lengths which are all in some hypothetical unit.

N-O is 2.00 units long. N=O is 1.00 unit long. $\text{N}\equiv\text{O}$ is 0.50 units long.

A possible Lewis structure for NO_3^- is:

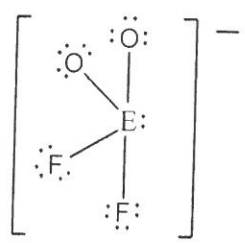


Average of any one N-O bond
 $= \frac{2 + 1 + 1}{3} = \frac{4}{3} = 1\frac{1}{3}$ bond

So length closer to single bond than a double bond.
 Which of the following values will be closest to the actual bond length for the bond labeled 1?

- a. 2.00 units **b. 1.67 units** c. 1.50 units d. 1.00 unit e. 0.75 units

5. In the Lewis structure below, E is a general symbol for some element.



Formula = EO_2F_2^-
 Valence e^- in Lewis structure = $34e^-$
 $34 = x + 2(6) + 2(7) + 1$
 $x = 7 =$ valence electrons of central E atom.

E is a halogen. Since E has 10 electrons around it in the Lewis structure, can't be F (row 2 elements never exceed the octet rule), so only other halogen is Br.
 Which of the following elements could be E?

- a. S b. F c. P **d. Br** e. O

molar mass $\text{Al}_2\text{O}_3 = 2(26.98\text{g}) + 3(16.00\text{g}) = 101.96\text{g/mol}$

6. Pure aluminum oxide, Al_2O_3 , occurs in nature as a mineral called corundum, which is noted for its hardness and resistance to attack by acids. Corundum's density is 3.97 g/mL. Calculate the number of atoms of aluminum in 15.00 mL of corundum.

- a. 7.03×10^{23} atoms Al b. 6.40×10^{22} atoms Al c. 3.52×10^{21} atoms Al
 d. 1.16×10^{23} atoms Al e. 3.52×10^{23} atoms Al

$$\frac{15.00\text{ mL} \times 3.97\text{ g Al}_2\text{O}_3}{1\text{ mL}} \times \frac{1\text{ mol Al}_2\text{O}_3}{101.96\text{ g}} \times \frac{2\text{ mol Al}}{1\text{ mol Al}_2\text{O}_3} = 6.022 \times 10^{23}\text{ atoms Al}$$

$$\frac{6.022 \times 10^{23}\text{ atoms Al}}{1\text{ mol Al}} = 7.03 \times 10^{23}\text{ atoms Al}$$

7. Which of the following statements is **false**?

- a. In general, transition metals ^{lose} gain electrons to form stable ions when in ionic compounds. *In ionic compounds, metals lose electrons to form cations.*
- b. Noble gases are found on the right side of the periodic table. *Group 8A*
- c. Alkaline earth metals form stable +2 ions in compounds.
- d. In general, the halogens are nonmetals.
- e. In general, when a metal reacts with a nonmetal, an ionic compound is produced.

8. Total number of electrons = $2 + 1 + 3 + 1 + 2 + 1 + 1 = 11$ electrons
The -3 charged ion of an element has an excited state electron configuration of $1s^2 2s^1 2p^3 3s^1 3p^2 4s^1 3d^1$. Which of the following is the identity of the ion?

- a. B^{3-} b. O^{3-} c. Na^{3-} d. Sc^{3-} e. Si^{3-}

Only O^{3-} has 11 electrons, so it is the only possible correct answer.

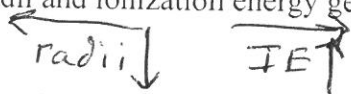
9. For a hydrogen atom, how many of the following five electronic transitions are **exothermic**? ~~Exothermic~~ *Emissions are exothermic (energy released). We have an emission when we go from a higher energy level to a lower energy level. The emissions are*

$n=6$ to $n=1$ $n=2$ to $n=3$ $n=3$ to $n=5$ $n=4$ to $n=2$ $n=126$ to $n=61$

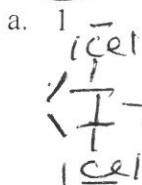
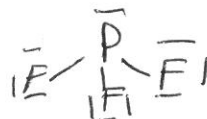
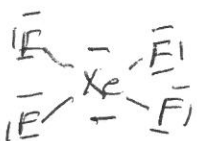
- a. 1 b. 2 c. 3 d. 4 e. 5 (All are exothermic.)
- $6 \rightarrow 1, 4 \rightarrow 2, \text{ and } 126 \rightarrow 61$. The other two transitions ($2 \rightarrow 3$ and $3 \rightarrow 5$) are absorptions (endothermic).*

10. Which of the following statements is **false**?

- a. The electron affinity of N is equal to the ionization energy of N^+ . *These two processes are not the same.*
- b. Br has a negative (exothermic) electron affinity. *-as do all halogens*
- c. The electron affinities of the noble gases are positive (endothermic).
- d. Ionization energies for the various elements are positive (endothermic).
- e. The radii and ionization energy general trends are opposite of each other.



11. How many of the following five compounds have a Lewis structure where the central atom has two (2) lone pairs?

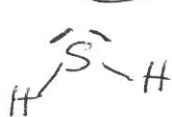
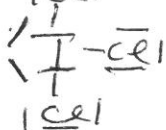


b. 2

c. 3

d. 4

e. 5 (all)



Only PF_3 does not have 2 lone pairs on the central atom.

12. How many of the following four calculations (I-IV) give an answer with 3 significant figures?

yes I. $10.01 + 2.3 + 0.01 = 12.32 = 12.3$

yes II. 27.0×0.0300
3sf x 3sf gives 3sf answer

no III. $16 \times (30 + 100 - 6)$
at most a 2 sig. fig answer

no IV. $\frac{49.1 - 40.0}{805} = \frac{9.1}{805}$
difference known to tenths place
2sf / 3sf \Rightarrow gives 2 sig fig answer

- a. 0 (none) b. 1 c. 2 d. 3 e. 4 (all)



13. Consider the combustion of $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, an organic compound. What is the sum of the coefficients of all the reactants and products in the best balanced equation?

- a. 22 b. 36 c. 42 d. 56 e. 70
1 + 12 + 12 + 11 = 36; combustion means reacting something with O_2

In a combustion reaction of an organic compound that only contains C, H, and O, CO_2 and H_2O are the products.

14. Which of the following statements is false?

- a. The three 5p atomic orbitals all have the same energy but have different orientations about the x, y, and z axes. *different orientations.*
- b. 2d atomic orbitals do not exist in the quantum mechanical model of the atom.
- c. The lanthanide series elements have ground state electrons in the 4f atomic orbitals. *ground state = lowest energy arrangement*
- d. For an atom, there is only one ground state electron configuration.
- e. For neutral atoms, the 6p atomic orbitals should be higher in energy than the 4f atomic orbitals. *from periodic table, 4f orbitals fill before the 6p orbitals. so 4f are lower energy.*

15. How many of the following four statements (I-IV) is/are true?

- I. As successive electrons are removed from an atom, size decreases. *As electrons are removed, the resulting species has fewer electrons held by the same number of protons. The outer electrons are held more tightly, resulting in smaller size, larger IE.*
- II. As successive electrons are removed from an atom, ionization energy increases.
- III. For an isoelectronic series, the species with the most negative charge has the smallest ionization energy. *Most negative ion has the fewest protons holding the same number of electrons. Size increases and IE decreases.*
- IV. In general, the atomic radius of neutral atoms decreases when going left to right across a row in the periodic table.

- a. 0 (None are true.) b. 1 c. 2 d. 3

e. 4 [All four statements (I-IV) are true.]

Electronegativity trend.

N	O	↑	Electronegativity trend.
P	S		

 H has an electronegativity value identical to P. So P-H bond is a nonpolar bond.

16. The most polar bond has the largest electronegativity difference between the atoms in bond. Since P has the lowest electronegativity value and O has the largest EN value, the P-O bond is most polar covalent.

17. Each molecule of cortisone contains 21 atoms of carbon (plus other atoms). If 10.00 g of cortisone contains 7.00 g of carbon, what is the molar mass of cortisone?

Molar mass = $\frac{\text{mass}}{\text{moles}} = \frac{10.00 \text{ g cortisone}}{0.02775 \text{ mol cortisone}}$

a. 177 g/mol b. 252 g/mol c. 288 g/mol
 d. 313 g/mol e. 360. g/mol

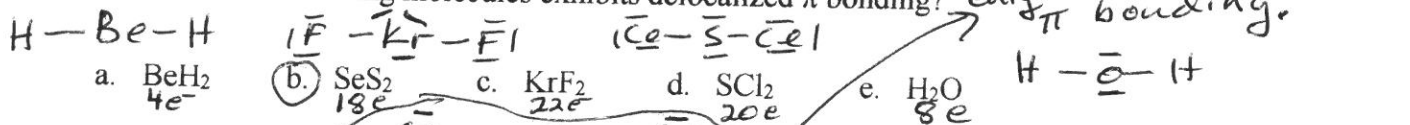
$\text{mol cortisone} = \frac{7.00 \text{ g C}}{12.01 \text{ g/mol C}} \left(\frac{1 \text{ mol C}}{12.01 \text{ g C}} \right) \left(\frac{21 \text{ mol C}}{1 \text{ mol cortisone}} \right) = 0.02775 \text{ mol cortisone}$

Molar mass = $\frac{10.00 \text{ g cortisone}}{0.02775 \text{ mol cortisone}} = 360.3 = 360. \text{ g/mol}$

18. Which of the following is named incorrectly?

- a. H₂SO₄ sulfuric acid ok
- b. Ca₃P₂ tricalcium diphosphide NO calcium phosphide is correct for this ionic compound.
- c. NH₄ClO₃ ammonium chlorate ok
- d. Cu(C₂H₃O₂)₂ copper(II) acetate ok
- e. P₄O₆ tetraphosphorus hexoxide ok

19. Which of the following molecules exhibits delocalized π bonding?



20. How many of the following five molecules have a linear shape?

Note: these are the same molecules used in the previous question. See above for Lewis structures

- a. 1
 - b. 2
 - c. 3
 - d. 4
 - e. 5 (all)
- SeS₂ angular bent KrF₂ SCl₂ angular bent H₂O angular bent

SeS₂ has ~120° bond angle. SCl₂ and H₂O have ~109° bond angle.

21. Rank the following ions from smallest radius to largest radius?

Ca²⁺ and S²⁻ are isoelectronic (18e⁻). Ca²⁺, with more protons, will be smaller than S²⁻. As³⁻ is isoelectronic with Se²⁻. As³⁻, with fewer protons, will be larger than Se²⁻. From the general radius trend, Se is larger than S, so Se²⁻ is larger than S²⁻.

Putting all this together, As³⁻ must be larger than S²⁻. The correct order is Ca²⁺ < S²⁻ < As³⁻.

22. How many of the following are **correct** ground state electron configurations for the elements listed?

Correct C: $[\text{He}]2s^22p^2$

Correct Cl: $[\text{Ne}]3s^23p^5$

NO Sc: $[\text{Ar}]4s^03d^3$

Sc: $[\text{Ar}]4s^23d^1$ is correct.

Correct Cu: $[\text{Ar}]4s^13d^{10}$

Cu is an exception to know.

Correct Element #115: $[\text{Rn}]7s^25f^{14}6d^{10}7p^3$

a. 1

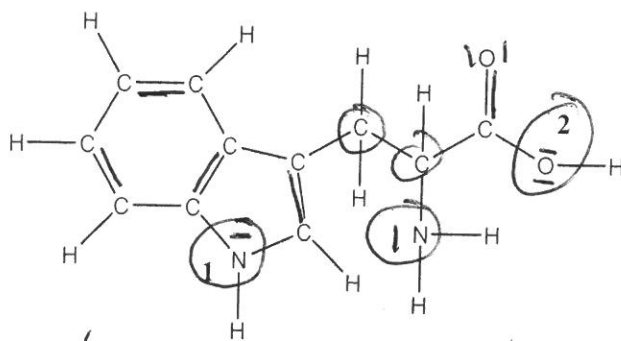
b. 2

c. 3

d. 4

e. 5 (All are correct ground state electron configurations.)

Tryptophan is the organic molecule largely responsible for the sleepy feeling you get after eating turkey. The skeletal structure of tryptophan is shown below. Complete a Lewis structure and answer the next two questions.



Follow "Organic" Rules to complete Lewis structure.

C: 4 bonds + 0 lone pairs
N: 3 " + 1 " "
O: 2 " + 2 " "

23.

The circled atoms have tetrahedral geometry (109° bond angles), so they are all sp^3 hybridized. The other C and N atoms exhibit trigonal planar geometry (120° bond angles), so they exhibit sp^2 hybridization.

How many atoms in tryptophan are sp^3 hybridized?

a. 2

b. 3

c. 4

d. 5

e. 6

24.

What are the approximate bond angles around the nitrogen atom labeled 1 and the oxygen atom labeled 2, respectively? N_1 and O_2 both exhibit 109° bond angles since they both have tetrahedral geometry about the central atom.

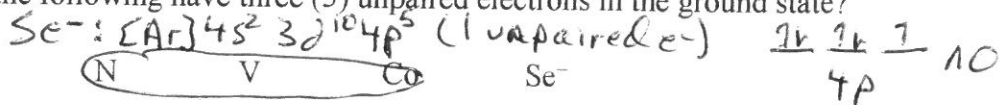
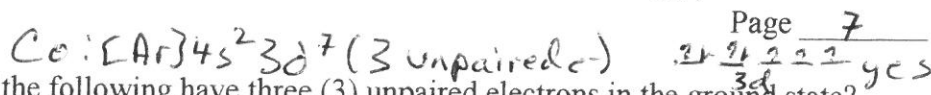
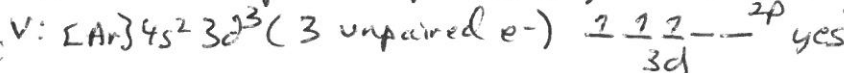
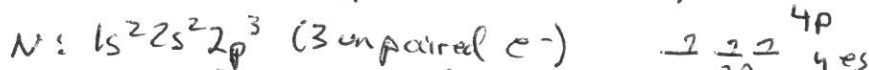
a. 109°; 109°

b. 120°; 109°

c. 120°; 120°

d. 109°; 180°

e. 90°; 120°



25. How many of the following have three (3) unpaired electrons in the ground state?

- a. 1 b. 2 **c. 3** d. 4 e. 5 (all)

26. How many of the following five statements (I-V) about hydrogen is/are true?

- follows trend $IE \uparrow$
 T I. H has a smaller ionization energy than He.
 F II. H⁻ has a smaller size than H. H⁻ with more electrons is bigger.
 F III. H forms an ionic bond with F. H-F is a polar covalent bond.
 F IV. H is considered to be a metal. H is a nonmetal.
 T V. H does not have a second ionization energy. *only has 1 electron so can't lose a second electron.*

- a. 1 **b. 2** c. 3

e. 5 [All of these statements (I-V) are true.]

Na₂X is composed of Na⁺ and X²⁻ ions.

27. The isotope of an unknown element, X, has a mass number of 79. The most stable ion of the isotope has 36 electrons which forms a binary compound with sodium having a formula of Na₂X. Which of the following statements (a-d) is/are true?

- X²⁻ has 36 electrons, so X has 34 protons and X = Se.*
 T a. The binary compound formed between X and fluorine will be a covalent compound.
 F b. The isotope of X contains 38 protons. *34*
 F c. The isotope of X contains 41 neutrons. *45 79 - 34 = 45 neutrons*
 F d. The identity of X is strontium, ~~Se~~ Se
 e. All of the above statements (a-d) are true.

Se-F will form a covalent bond (two nonmetals).

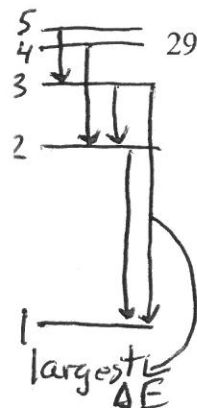
28. A certain transition metal ion (Mⁿ⁺) forms a compound with sulfur (M_xS_y). The molar mass of the compound is 298.4 g/mol. If the charge on the transition metal ion is +3, what is the identity of the transition metal, M? *Formula: M³⁺ + S²⁻ → M₂S₃*

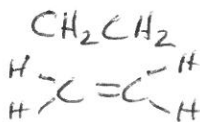
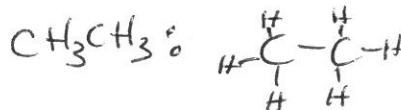
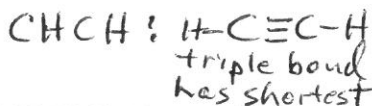
$298.4 \text{ g/mol} = 2(\text{molar mass } M) + 3(32.07)$, molar mass $M = 101.1 \text{ g/mol}$

a. Ti b. Mo c. Ir **d. Ru** e. Cf
From periodic table, M = Ru.

29. Which of the following electronic transitions for a one electron atom or ion corresponds to an emission of electromagnetic radiation having the shortest wavelength?

- As diagram to the left illustrates, as n increases, the energy levels get closer together ($E_n = -R_H/n^2$). The shortest wavelength has the largest E_{photon} ($E = hc/\lambda$), so the transition with the largest ΔE will have the shortest wavelength emission. This is the 3 → 1 transition.*
- a. n = 5 → n = 3 b. n = 4 → n = 2 c. n = 3 → n = 2
 d. n = 2 → n = 1 **e. n = 3 → n = 1**





30. Which of the following organic molecules has the carbon-carbon bond with the shortest bond length? For the skeletal structures, the two carbon atoms are bonded to each other with the other atoms bonded to the carbons. Note that the bond which is strongest will have the shortest bond length.



The triple bond in CHCH will be the strongest bond, so it has the shortest bond length.

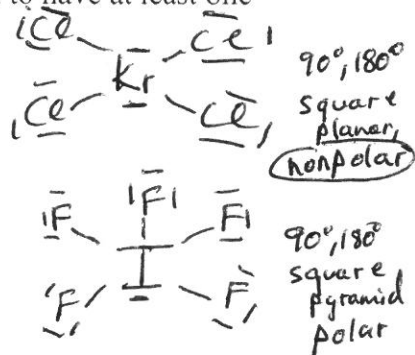
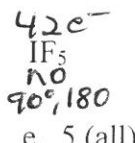
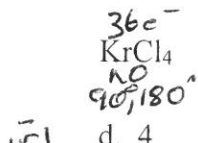
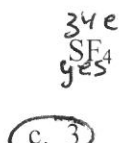
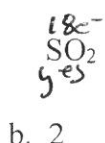
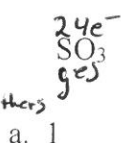
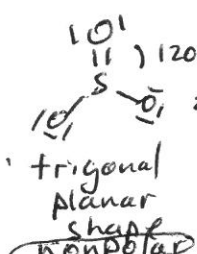
31. To remove an electron, take it to the $n = \infty$ state. Consider an electron for a hydrogen atom that is in an excited state. The maximum wavelength of electromagnetic radiation that can completely remove (ionize) the electron from this H atom is 3283 nm. What is the initial excited state for the electron ($n = ?$)?

$n_1 = n, n_2 = \infty$ $\Delta E = -R_H \left(\frac{1}{n_2^2} - \frac{1}{n_1^2} \right) = -R_H \left(\frac{1}{\infty^2} - \frac{1}{n^2} \right)$, $\Delta E = R_H/n^2$

- a. $n = 2$ b. $n = 3$ c. $n = 4$ d. $n = 5$ e. $n = 6$

$\Delta E = E = hc/\lambda = \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s} (2.998 \times 10^8 \text{ m/s})}{3283 \times 10^{-9} \text{ m}} = 6.05 \times 10^{-20} \text{ J}$
Solving: $\frac{6.05 \times 10^{-20} \text{ J}}{R_H} = \frac{2.17 \times 10^{-18} \text{ J}}{n^2}$
 $n = 6$

32. How many of the following five compounds are predicted by VSEPR to have at least one bond angle that is 120° ?



33. How many of the following five compounds are polar? Note: These are the same compounds used in the previous problem.

Bond dipoles are symmetrically arranged in SO_3 and $KrCl_4$, so bond dipoles cancel each other out and these compounds are nonpolar.

The bond dipoles are not symmetrically arranged in SO_2 , SF_4 , and IF_5 . These three compounds will be polar.

34. My answers for the chemistry 102 exam should be graded with the answer sheet associated with:

- a. Form A b. Form B c. Form C d. Form D e. Form E