

Choose *one* best answer for each of the following questions. (161 points total: 5 points each for Questions 2–33, 1 point for Question 1). Please mark your answers on the scantron sheet using a #2 pencil and also mark your answers on the exam itself. You may use the blank pages for calculations.

1. Please fill in “B” for question 1 on your scantron sheet because you have Version B of the exam:

(b) Fill in “B”

2. Which is the correct formula for potassium chlorate

- (a)  $\text{KClO}_4$
- (b)  $\text{KClO}_3$
- (c)  $\text{K}_2\text{ClO}_4$
- (d)  $\text{K}_2\text{ClO}_3$
- (e)  $\text{K}(\text{ClO}_3)_2$

3. What is the mass of one formula unit of sodium oxide?

- (a) 38.99 amu
- (b) 54.99 amu
- (c) 61.98 amu
- (d) 77.98 amu
- (e) 83.98 amu

4. How many ions exist in each formula unit of iron (III) phosphate?

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

5. A sample of gas in a 4.00 L container contains 0.50 mol  $\text{N}_2$  and 0.80 mole  $\text{O}_2$ . What is the total pressure in the container if the temperature is  $20.^\circ\text{C}$ ?

- (a) 0.53 atm
- (b) 1.89 atm
- (c) 5.60 atm
- (d) 7.81 atm
- (e) 792 atm

6. Which statement is FALSE?
- (a) The most probable speed of the molecules in a gas is not dependent on the temperature
  - (b) At a given temperature in a container, the average kinetic energy of  $N_2$  molecules is the same as that of Ar atoms.
  - (c) When the pressure of a gas in a container is decreased by increasing the volume of the container at constant temperature, the most probable speed of the gas molecules remains the same.
  - (d) When the volume of a gas is increased, the gas molecules collide less frequently with the wall.
  - (e) At a given temperature in a container, the average speed of the  $N_2$  molecules is higher than that of the Ar atoms.
7. What volume of ammonia gas at STP, is produced when 2.10 L of nitrogen gas at STP, reacts with 6.30 L of hydrogen gas at STP?
- (a) 2.10 L
  - (b) 4.20 L
  - (c) 6.30 L
  - (d) 8.40 L
  - (e) 10.5 L
8. An ionic compound forms when sodium metal reacts with chlorine gas, and the yield is 100%. If the product of the reaction contains 2.0 moles of sodium ions, how many moles of chlorine gas molecules reacted with the sodium metal?
- (a) 1.0 mole
  - (b) 1.5 moles
  - (c) 2.0 moles
  - (d) 3.0 moles
  - (e) 4.0 moles
9. If 28.7 g of ammonium sulfate is dissolved in 150. mL of water, what is the concentration of sulfate ions?
- (a) 0.190 M
  - (b) 0.725 M
  - (c) 1.45 M
  - (d) 1.67 M
  - (e) 2.90 M

10. Given the following solubility rules:

### Solubility Rules for Ionic Compounds in Water

#### Soluble Ionic Compounds

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1. All common compounds of Group 1A(1) ions ( $\text{Li}^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ , etc) and ammonium ion are soluble.
2. All common nitrates ( $\text{NO}_3^-$ ), acetates ( $\text{CH}_3\text{COO}^-$  or  $\text{C}_2\text{H}_3\text{O}_2^-$ ), and most perchlorates ( $\text{ClO}_4^-$ ) are soluble.
3. All common chlorides ( $\text{Cl}^-$ ), bromides ( $\text{Br}^-$ ) and iodides ( $\text{I}^-$ ) are soluble, *except* those of  $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Cu}^+$ , and  $\text{Hg}_2^{2+}$ .
4. All common sulfates ( $\text{SO}_4^{2-}$ ) are soluble, *except* those of  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Ag}^+$ , and  $\text{Pb}^{2+}$ .

#### Insoluble Ionic Compounds

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1. All common metal hydroxides are insoluble, *except* those of Group 1A(1) and the larger members of Group 2A(2)(beginning with  $\text{Ca}^{2+}$ ).
  2. All common carbonates ( $\text{CO}_3^{2-}$ ) and phosphates ( $\text{PO}_4^{3-}$ ) are insoluble, *except* those of Group 1A(1) and  $\text{NH}_4^+$ .
  3. All common sulfides are insoluble *except* those of Group 1A(1), Group 2A(2) and  $\text{NH}_4^+$ .
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Predict what, if anything, will precipitate from mixing aqueous solutions of copper (II) nitrate and potassium sulfate?

- (a) Copper (II) nitrate will precipitate
- (b) Potassium nitrate will precipitate
- (c) Copper (II) sulfate will precipitate
- (d) Potassium sulfate will precipitate
- (e) Nothing will precipitate.

11. Identify the spectator ions for the aqueous reaction of strontium chloride and potassium sulfate. The solubility rules are provided in problem 12.

- (a)  $\text{K}^+(aq)$  and  $\text{SO}_4^{2-}(aq)$
- (b)  $\text{Sr}^{2+}(aq)$  and  $\text{SO}_4^{2-}(aq)$
- (c)  $\text{K}^+(aq)$  and  $\text{Cl}^-(aq)$
- (d)  $\text{Sr}^{2+}(aq)$  and  $\text{Cl}^-(aq)$
- (e)  $\text{Sr}^{2+}(aq)$ ,  $\text{SO}_4^{2-}(aq)$ ,  $\text{K}^+(aq)$  and  $\text{Cl}^-(aq)$

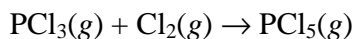
12. Calculate the volume of a 1.75 M calcium hydroxide solution required to titrate 31.2 mL of a 0.850 M hydrochloric acid solution.

- (a) 1.89 mL
- (b) 3.79 mL
- (c) 7.58 mL
- (d) 15.2 mL
- (e) 30.3 mL

13. When 15.0 L of water is added to 1.5 liter of a 2.0 M solution of potassium phosphate (*aq*), what is the final concentration?

- (a) 0.10 M
- (b) 0.12 M
- (c) 0.18 M
- (d) 0.20 M
- (e) 20. M

14. What is the percent yield for the reaction below if 7.23 g of  $\text{PCl}_5$  are formed when 5.67 g of  $\text{PCl}_3$  react with excess  $\text{Cl}_2$ ?



- (a) 22.2 %
- (b) 51.7 %
- (c) 78.4 %
- (d) 84.1 %
- (e) 128 %

15. If 465 J of heat is absorbed by a 50.0 g piece of gold at 25.0°C, what is the final temperature? The specific heat capacity of gold is 0.129 J/g·K

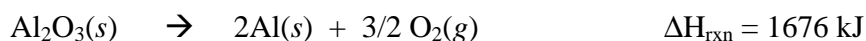
- (a) 97.1°C
- (b) 101.2°C
- (c) 133.7°C
- (d) 205.1°C
- (e) 370.2°C

16. Which one of the following is exothermic?

- (a) The condensation of water on a cold glass
- (b) The melting of ice.
- (c) The reaction:  $2\text{SO}_3(g) + 198.4 \text{ kJ} \rightarrow 2\text{SO}_2(g) + \text{O}_2(g)$
- (d)  $\text{Ar}(l) \rightarrow \text{Ar}(g)$
- (e) None of the above

17. How much energy is required to *completely* remove the electrons from one mole of hydrogen atoms in their ground states?
- (a) 799 kJ
  - (b) 821 kJ
  - (c) 844 kJ
  - (d) 907 kJ
  - (e) 1310 kJ

18. The reaction that occurs when bauxite (mostly aluminum oxide) is thermally decomposed is:



How much heat is required to produce 5.65 g of aluminum? (Assume that there is enough bauxite to produce this amount of aluminum.)

- (a) 87.7 kJ
  - (b) 95.6 kJ
  - (c) 142 kJ
  - (d) 175 kJ
  - (e) 350 kJ
19. A 4.556 g sample of zinc was immersed into a coffee cup calorimeter containing 150.0 mL of 3.0 M HCl. It reacted with the acid and the temperature increased from 20.00°C to 37.14°C. Calculate  $\Delta H$  for the reaction of 4.556 g of zinc. The density of the solution is 1.098 g/mL and the specific heat capacity is 4.10 J/g·K; the heat capacity of the empty cup is 26 J/K. Assume that the heat capacity contribution from the zinc is negligible.
- (a) -11.52 kJ
  - (b) -12.02 kJ
  - (c) +11.58 kJ
  - (d) +12.02 kJ
  - (e) +0.766 kJ
20. What is the wavelength of the photon that is absorbed when an electron in the hydrogen atom undergoes a transition from the  $n=2$  state to the  $n=3$  state? Note: the number has been reduced to 4 significant figures.
- (a) 1066 nm
  - (b) 879.9 nm
  - (c) 656.5 nm
  - (d) 152.3 nm
  - (e) Photons cannot be absorbed by hydrogen atoms.

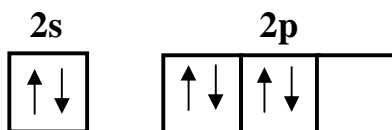
21. Which of the following statements is scientifically true?

- (a) For a hydrogenic orbital or ion, the energies of the orbitals depend on the value of  $l$ .
- (b) For a many electron atom, the energies of the orbitals depend only on the value of  $n$ .
- (c) In a He atom, the  $2s$  orbitals are lower in energy than the  $2p$  orbitals.
- (d) An electron in the ground state of a H atom experiences more shielding than an electron in the ground state of a Li atom.
- (e) The Bohr model works for the  $\text{Be}^+$  because it is a hydrogenic ion.

22. Which one of the following equations correctly represents the process relating to the electron affinity of an unknown atom X?

- (a)  $\text{X}(s) \rightarrow \text{X}^+(g) + e^-$
- (b)  $\text{X}_2(g) \rightarrow \text{X}^+(g) + \text{X}^-(g)$
- (c)  $\text{X}(g) + e^- \rightarrow \text{X}^-(g)$
- (d)  $\text{X}^-(g) \rightarrow \text{X}(g) + e^-$
- (e)  $\text{X}(g) \rightarrow \text{X}^+(g) + e^-$

23. In chemistry, the following partial orbital diagram represents:



- (a) the ground state electron configuration of oxygen
- (b) an excited state electron configuration of oxygen
- (c) the ground state electron configuration of carbon
- (d) an excited state electron configuration of carbon
- (e) an excited state electron configuration of sulfur

24. How many electrons can have the quantum numbers  $n = 4$  and  $l = 2$ ?

- (a) 2
- (b) 5
- (c) 7
- (d) 10
- (e) 14

25. Which of the following has the set of atoms correctly arranged in order of *increasing* size (from smallest to largest).
- (a) Sr < Ca < Cl < Br
  - (b) Ca < Sr < Cl < Br
  - (c) Sr < Ca < Br < Cl
  - (d) Br < Cl < Sr < Ca
  - (e) Cl < Br < Ca < Sr
26. Which of the following is the full ground state electron configuration of the monoatomic ion most likely to be formed by oxygen?
- (a)  $1s^2 2s^2 2p^6 3s^2 3p^4$
  - (b)  $1s^2 2s^2 2p^6 3s^2$
  - (c)  $1s^2 2s^2 2p^4$
  - (d)  $1s^2 2s^2 2p^6 3s^2 3p^6$
  - (e)  $1s^2 2s^2 2p^6$
27. The H–P–H bond angles in the phosphonium cation  $\text{PH}_4^+$  are:
- (a) exactly  $90^\circ$
  - (b) exactly  $120^\circ$
  - (c) less than  $109.5^\circ$
  - (d) exactly  $109.5^\circ$
  - (e) more than  $120^\circ$
28. Which one of the following compounds will have the *largest* lattice energy?
- (a)  $\text{BeF}_2$
  - (b)  $\text{BeO}$
  - (c)  $\text{LiF}$
  - (d)  $\text{KF}$
  - (e)  $\text{CsF}$
29. How many equivalent resonance structures can be drawn for the nitrate anion?
- (a) 0
  - (b) 1
  - (c) 2
  - (d) 3
  - (e) 4

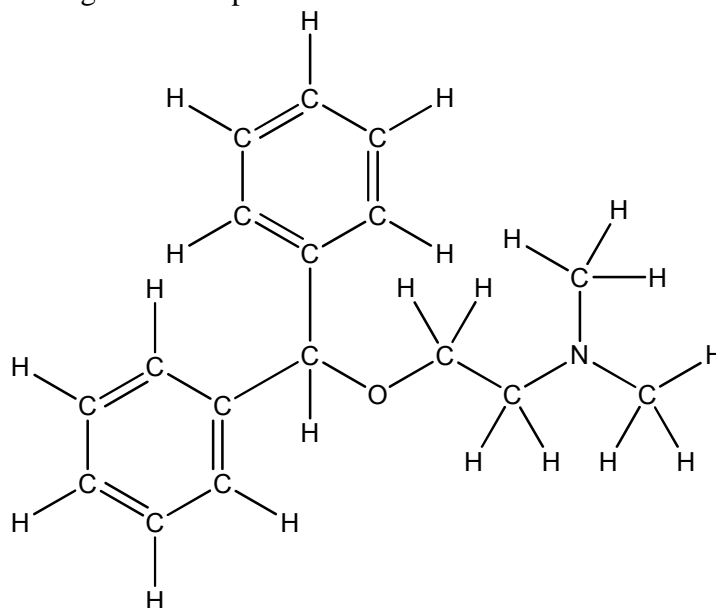
30. Which of the following molecules has a see-saw shape?

- (a)  $\text{SeF}_4$
- (b)  $\text{NH}_4^+$
- (c)  $\text{BF}_4^-$
- (d)  $\text{PCl}_5$
- (e)  $\text{IF}_5$

31. Which of the following molecules has the *largest* dipole moment?

- (a)  $\text{BF}_3$
- (b)  $\text{SiF}_4$
- (c)  $\text{F}_2$
- (d)  $\text{IF}_3$
- (e)  $\text{XeF}_4$

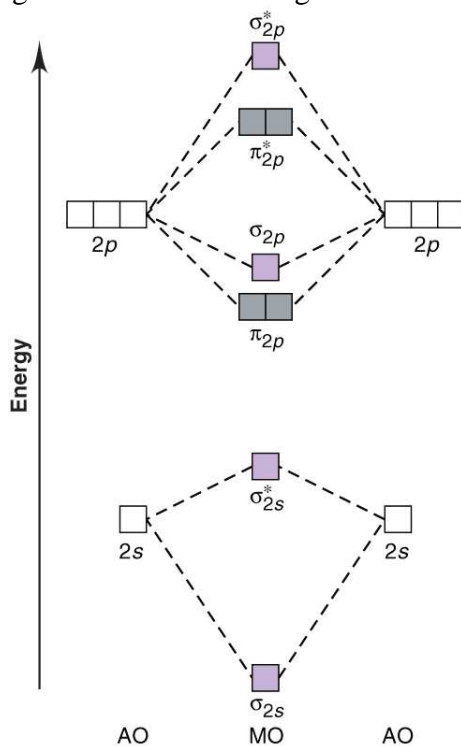
32. How many  $\text{sp}^3$  hybridized atoms are in one molecule of diphenhydramine/benadryl (shown below) assuming ideal bond angles? Lone pairs are not shown.



- (a) 7
- (b) 12
- (c) 13
- (d) 15
- (e) 18

33. How would you classify the bonds in the benzene molecule  $C_6H_6$ ? It will be helpful to draw a Lewis structure.
- 6  $\sigma$  bonds
  - 6  $\sigma$  bonds and 3  $\pi$  bond
  - 12  $\sigma$  bonds and 2  $\pi$  bonds
  - 12  $\sigma$  bonds and 3  $\pi$  bonds
  - 12  $\sigma$  bonds and 6  $\pi$  bonds

Use the following molecular orbital diagram for the next question 33.



34. Which of the following has the set of molecules correctly arranged in order of *increasing* bond order?
- $B_2 < B_2^- < B_2^+$
  - $B_2 < B_2^+ < B_2^-$
  - $B_2^- < B_2^+ < B_2$
  - $B_2^- < B_2 < B_2^+$
  - $B_2^+ < B_2 < B_2^-$

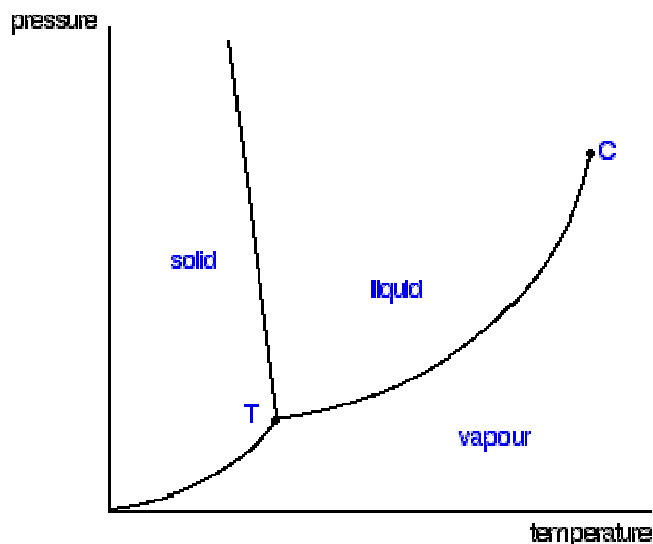
35. Calculate the enthalpy of formation ( $\Delta H_f^\circ$ ) of gaseous hydrazine ( $\text{H}_2\text{NNH}_2$ ) using the bond energies given in the above table. Recall that the enthalpy of formation refers to the reaction in which one mole of the substance is formed from the elements in their standard state.
- (a)  $-85 \text{ kJ/mol}$   
 (b)  $+85 \text{ kJ/mol}$   
 (c)  $-173 \text{ kJ/mol}$   
 (d)  $+173 \text{ kJ/mol}$   
 (e)  $-700 \text{ kJ/mol}$

Table 9.3			
Average Bond Energies (kJ/mol)			
H – H	432	C – O	358
H – O	467	C = O	745
C – H	413		(799 in $\text{CO}_2$ )
C – C	347	C – F	453
C = C	614	C – Cl	339
$\text{N} \equiv \text{N}$	945	C – Br	276
O = O	498 ( $\text{O}_2$ )	Cl – Cl	243
N – N	160	O – Cl	203
N = N	418	N – H	391
		N – Cl	200

36. Calculate the total heat needed to convert 10.0 g of ice at  $-5.00 \text{ }^\circ\text{C}$  to liquid water at  $0.5 \text{ }^\circ\text{C}$  if the pressure remains constant at 1 atm:
- mp at 1 atm:  $0.00 \text{ }^\circ\text{C}$        $\Delta H_{\text{fus}}$ :  $6.02 \text{ kJ/mol}$   
 bp at 1 atm:  $100. \text{ }^\circ\text{C}$        $\Delta H_{\text{vap}}$ :  $40.7 \text{ kJ/mol}$   
 $c_{\text{solid}} = 2.09 \text{ J/g}\cdot\text{K}$        $c_{\text{liquid}} = 4.21 \text{ J/g}\cdot\text{K}$        $c_{\text{gas}} = 1.84 \text{ J/g}\cdot\text{K}$
- (a)  $72.2 \text{ kJ}$   
 (b)  $4.20 \text{ kJ}$   
 (c)  $72.5 \text{ kJ}$   
 (d)  $4.16 \text{ kJ}$   
 (e)  $3.47 \text{ kJ}$
37. Diethyl Ether has a  $\Delta H_{\text{vap}}$  of  $29.1 \text{ kJ/mol}$  and a vapor pressure of  $0.703 \text{ atm}$  at  $25.0 \text{ }^\circ\text{C}$ . What is the vapor pressure at  $31.0 \text{ }^\circ\text{C}$ ? Use the Clausius Clapeyron Eq:  $\ln(P_2/P_1) = -\Delta H_{\text{vap}}/R(1/T_2 - 1/T_1)$  (Remember to convert to degrees Kelvin.)
- (a)  $0.886 \text{ atm}$   
 (b)  $0.557 \text{ atm}$   
 (c)  $0.760 \text{ atm}$   
 (d)  $1.00 \text{ atm}$   
 (e) None of the above

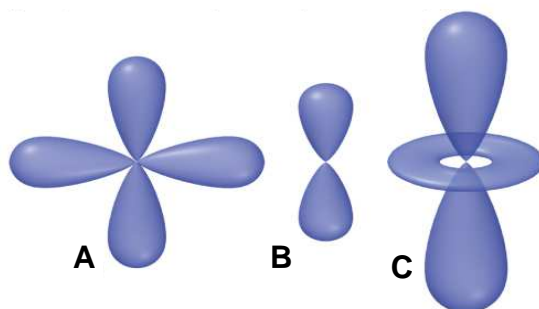
38. Which of the following is true about kinetic energy,  $E_k$ , and potential energy,  $E_p$ , when ethyl alcohol at  $40^\circ\text{C}$  is compared with ethyl alcohol at  $20^\circ\text{C}$ ?
- (a)  $E_k(40^\circ\text{C}) < E_k(20^\circ\text{C}); E_p(40^\circ\text{C}) \approx E_p(20^\circ\text{C})$
  - (b)  $E_k(40^\circ\text{C}) > E_k(20^\circ\text{C}); E_p(40^\circ\text{C}) \approx E_p(20^\circ\text{C})$
  - (c)  $E_k(40^\circ\text{C}) \approx E_k(20^\circ\text{C}); E_p(40^\circ\text{C}) < E_p(20^\circ\text{C})$
  - (d)  $E_k(40^\circ\text{C}) \approx E_k(20^\circ\text{C}); E_p(40^\circ\text{C}) > E_p(20^\circ\text{C})$
  - (e)  $E_k(40^\circ\text{C}) > E_k(20^\circ\text{C}); E_p(40^\circ\text{C}) > E_p(20^\circ\text{C})$
39. A sample of octane in equilibrium with its vapor in a closed 1.0-L container has a vapor pressure of 50.0 torr at  $45^\circ\text{C}$ . The container's volume is increased to 2.0 L at constant temperature and the liquid/vapor equilibrium is reestablished. What is the vapor pressure?
- (a)  $> 50.0$  torr
  - (b) 50.0 torr
  - (c) 25.0 torr
  - (d) The mass of the octane vapor is needed to calculate the vapor pressure.
  - (e) The external pressure is needed to calculate the vapor pressure
40. Which of the following diatomic molecules has the lowest boiling point?
- (a)  $\text{F}_2$
  - (b)  $\text{Cl}_2$
  - (c)  $\text{Br}_2$
  - (d)  $\text{I}_2$
  - (e) All of these molecules have the same boiling point.

41. We have found a sample of a mysterious substance X and the only information given to us was a phase diagram, shown below. From this phase diagram, which of the following statements are *true*?

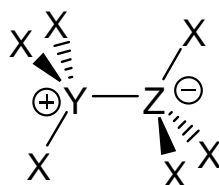


- (a) The density of solid X is greater than the density of liquid X.  
(b) It is possible at low temperatures to sublime X.  
(c) At temperature above point T, the solid phase cannot exist.  
(d) Both (a) and (b) are true.  
(e) Both (b) and (c) are true.
42. In which of the following substances would you expect hydrogen bonding forces to be important?
- (a)  $\text{NH}_3$   
(b)  $\text{CH}_4$   
(c)  $\text{BH}_3$   
(d)  $\text{PCl}_3$   
(e)  $\text{BCl}_3$
43. Which of the following statements are *true* regarding molecular forces.
- (a) Intramolecular forces are weaker than intermolecular forces.  
(b) Hydrogen bonding is not an important force in aqueous solvents.  
(c) Dispersion forces are responsible for the strongest intramolecular interactions.  
(d) Hydrogen bonds are a type of intermolecular force.  
(e) Polarizability is not an important factor in dispersion forces among molecules with heavy elements.

44. Extra Credit Problem: Chose the answer which gives the proper letter name for each of these orbitals.



- (a) A, B, and C are all *p orbitals*  
(b) B and C are *p orbitals* and A is a *d orbital*  
(c) B is a *p orbital*, A and C are *d orbitals*  
(d) A is a *d orbital*, B is a *p orbital* and C is a *hybridized orbital*  
(e) B is a *p orbital*, A and C are *hybridized orbitals*.
45. Extra Credit Problem: For the molecule depicted below, which choices of atoms are reasonable for X, Y, and Z?



- (a) X = H; Y = B; Z = N  
(b) X = H; Y = N; Z = B  
(c) X = F; Y = Al; Z = P  
(d) X = H; Y = N; Z = O  
(e) X = H; Y = O; Z = C