MCAT Subject Tests

Dear Future Doctor,

The following Subject Test and explanations contains questions not in test format and should be used to practice and to assess your mastery of the foundation content necessary for success on the MCAT. Simply memorizing facts is not sufficient to achieve high scores; however, an incomplete understanding of basic science knowledge will limit your ability to think critically. Think of building your content knowledge as learning the vocabulary and practicing MCAT-like questions as actually speaking.

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Sincerely,

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Kaplan Test Prep

General Chemistry Subject Test 1

1. What is the percentage by mass of sulfur in H_2SO_4? (Atomic wt.: S = 32, O = 16, H = 1)

A. 16%
B. 33%
C. 36%
D. 42%
E. Cannot be determined from the information given

2. For the reaction: A + B ∅ C, determine the order of the reaction with respect to B from the information given below.

Initial [A] (M)	Initial [B] (M)	Initial rate of formation of C (mol/L•min)
$2.5 \infty 10^{-6}$	$3 \infty 10^{-4}$	$5 \infty 10^{-3}$
$5 \infty 10^{-6}$	$3 \infty 10^{-4}$	$1 \infty 10^{-2}$
$1 \infty 10^{-5}$	$9 \infty 10^{-4}$	$1.8 \infty 10^{-1}$

A. zero order
B. first order
C. second order
D. third order
E. fourth order

3. A catalyst

A. changes _G for a reaction.
B. acts by increasing the rate of the forward reaction more than the reverse reaction.
C. raises the equilibrium constant of a system.
D. may have molecular weight as low as 1 or higher than 200,000.
E. does not react chemically during the course of a reaction.

Questions 4 and 5 refer to the information below:

	_H (kJ/mole) =
$H_2O(g)$ ∅ $H_2O(l)$	–44
$C(s) + O_2(g)$ ∅ $CO_2(g)$	–394
$H_2(g) + {}^1/_2O_2(g)$ ∅ $H_2O(l)$	–286
$C_2H_5OH(l) + 3O_2(g)$ ∅ $2CO_2(g) + 3H_2O(l)$	–1367

4. Calculate the enthalpy change for the reaction:

$2C(s) + 2H_2(g) + H_2O(l)$ ∅ $C_2H_5OH(l)$

A. –226 kJ/mole
B. +7 kJ/mole
C. +109 kJ/mole
D. +344 kJ/mole
E. +687 kJ/mole

5. What is the $\_H_f$ of $H_2O(g)$?

A. –330 kJ/mole
B. –286 kJ/mole
C. –242 kJ/mole
D. +242 kJ/mole
E. +330 kJ/mole

6. Gas A is at 30 °C and gas B is at 20°C. Both gases are at 1 atmosphere. What is the ratio of the volume of 1 mole of gas A to 1 mole of gas B?

A. 1:1
B. 2:3
C. 3:2
D. 303:293
E. 606:293

7. Which of the following elements has an ionic radius that is larger than its atomic radius?

A. Na
B. K
C. Mg
D. Al
E. Cl

8. When there are 2 electrons in the 3*s* subshell

A. they must be occupying different orbitals.
B. the Heisenberg uncertainty principle predicts that they must periodically jump to the 3*p* subshell.
C. the oxidation state of the atom must be +2.
D. they must have opposite spins.
E. they are oppositely charged.

9. When 1 mole of sulfur burns to form SO_2, 1300 calories are released. When 1 mole of sulfur burns to form SO_3, 3600 calories are released. What is _H when 1 mole of SO_2 is burned to form SO_3?

A. +3900 calories
B. –1950 calories
C. +1000 calories
D. –500 calories
E. –2300 calories

10. Which of the following elements is the most electronegative?

A. C
B. Si
C. Ge
D. Sn
E. Pb

11. If one mole of a gas originally at STP is placed in a container where the pressure is doubled and the absolute temperature (measured in K) is tripled, what is the new volume in liters?

A. 2.2 L
B. 5.6 L
C. 7.5 L
D. 11.2 L
E. 33.6 L

12. Which of the following is a property of nonmetals?

A. malleability and ductility
B. a shiny luster
C. ability to act as reducing agents
D. ease of oxidized
E. ability to act as good oxidizing agents

13. Given the unbalanced reaction below:

$Mg_3N_2 + H_2O \varnothing Mg(OH)_2 + NH_3$

what will be the sum of the coefficients when the reaction is balanced?

A. 9
B. 11
C. 12
D. 17
E. 19

14. How many moles of water are formed by a mixture of 100 grams of H_2 and 100 grams of O_2, assuming that the reaction goes to completion?

A. $\frac{100}{32} + \frac{100}{64}$
B. $100 + 2\left(\frac{100}{32}\right)$
C. $2\left(\frac{100}{32}\right)$
D. $100\left(\frac{100}{32}\right)$
E. $200\left(\frac{100}{32}\right)$

15. A 200 mL flask contains oxygen at 200 mmHg, and a 300 mL flask contains neon at 100 mmHg. The two flasks are then connected so that each gas fills their combined volumes. Assuming no change in temperature, what is the partial pressure of neon in the final mixture?

A. 60 mmHg
B. 80 mmHg
C. 100 mmHg
D. 150 mmHg
E 200 mmHg

16. Inelastic collisions occur between molecules in

A. real gases.
B. ideal gases.
C. fusion reactions.
D. Two of the above
E. All of the above

17. Which of the following is an assumption of the Kinetic Theory of Gases?

A. elastic collisions
B. space occupied by molecules of a gas dictated by van der Waals radii
C. interaction of molecules
D. non-random motion of molecules
E. pressure as the average kinetic energy of the molecules

18. The Haber Process for the production of ammonia is represented by the equation below:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 22 \text{ kcal}$$

Which of the following will be the effect of an increase in temperature on this process?

A. The yield of ammonia is increased because the reaction is exothermic.
B. The yield of ammonia is increased because the reaction is endothermic.
C. The yield of ammonia is decreased because the reaction is exothermic.
D. The yield of ammonia is decreased because the reaction is endothermic.
E. There will be no change in the yield of ammonia.

19. A complex ion of general formula AB_6^{3-} is known to have octahedral geometry. What is the hybridization of the central atom of this ion?

A. sp^3
B. sp^3d
C. sp^3d^2
D. sp^2
E. sp^2d

20. Which of the following is NOT a characteristic of transition elements?

A. multiple oxidation states
B. inner shells which may be incomplete
C. lie between Group IIA and IIIA on the periodic table
D. include heavy metals
E. located in each period of the periodic table

21. What is the number of half-filled orbitals in one ground state atom of atomic number 16?

A. 1
B. 2
C. 3
D. 4
E. 6

Questions 22 through 25 refer to the matching choices below:

A. inert gases
B. active metals
C. transition elements
D. active non-metals

22. Found in the middle of the fourth period.

23. Smallest atomic radii in first three periods.

24. Naturally occurring metals in pure form.

25. Highest ionization potential within a period.

Questions 26 and 27 refer to the following hypothetical reaction:

2 X(*g*) + Y(*g*) ∅ Z(*g*)

26. If stoichiometric quantities of X(*g*) and Y(*g*) are introduced into a sealed, rigid container at constant temperature with an initial pressure of 12 atmospheres, what will the pressure in the container be when the reaction is complete?

A. 12 atmospheres
B. 6 atmospheres
C. 4 atmospheres
D. 3 atmospheres
E. 2 atmospheres

27. If stoichiometric quantities of X(*g*) and Y(*g*) are placed in a sealed, flexible container with an initial volume of 30 liters at STP, what volume of Z(*g*) will be produced?

A. 10 liters
B. 30 liters
C. 90 liters
D. $3\ ^1/_2$ liters
E. 5 liters

28. As the atomic radii of elements in Group VIIA of the Periodic Table increases, the electronegativity

A. increases.
B. decreases.
C. remains the same.
D increases to a maximum and then decreases.
E. decreases to a minimum and then increases.

29. What is the empirical formula of a compound which on analysis is shown to consist of 12.5% hydrogen, 37.5% carbon, and 50% oxygen by mass?

A. CHO
B. CH_2O
C. CH_3O
D. CH_4O
E. C_2H_4O

30. Which of the following pairs contain the most chemically similar elements?

A. magnesium and potassium
B. oxygen and nitrogen
C. gold and platinum
D. potassium and sodium
E copper and lead

STOP! END OF TEST.

THE ANSWER KEY AND EXPLANATIONS BEGIN ON THE FOLLOWING PAGE.

GENERAL CHEMISTRY SUBJECT TEST 1

ANSWER KEY

1. B	**7. E**	**13. C**	**19. C**	**25. A**
2. C	**8. D**	**14. C**	**20. E**	**26. C**
3. D	**9. E**	**15. A**	**21. B**	**27. A**
4. B	**10. A**	**16. D**	**22. C**	**28. B**
5. C	**11. E**	**17. A**	**23. A**	**29. D**
6. D	**12. E**	**18. C**	**24. C**	**30. D**

EXPLANATIONS

1. B

The percent by mass of an element in a compound is calculated by multiplying the atomic mass of that element by the number of atoms of that element in one formula of the compound, then dividing by the total formula weight of the compound and, finally, converting the result to a percentage. (Atomic masses can be found on the Periodic Table and thus do NOT need to be memorized.) In this example, there is only one atom of sulfur per formula of hydrogen sulfate (sulfuric acid) so the calculation goes (1 x 32)/(2 + 32 + 64), or 32/98. Calculation can be avoided by noticing that 32/98 will be just slightly more than 32/100, or slightly more than 32%. Choice A is the result of incorrectly inserting the atomic number of sulfur (in place of its atomic mass) into the calculation; choices C and D are the results of random errors in calculation; choice E is provided for those who give up too easily. Recall that if all the numbers are available somewhere, then the answer can be determined and choices like E in this question can be eliminated.

2. C

The rate law for any reaction, A + B ∅ C, is given by: rate = $k[A]^x[B]^y$ where k is the rate constant at the temperature at which the reaction is carried out, [A] and [B] are the concentrations of the two reactants, and x and y are the reaction orders with respect to A and B respectively. This question asks us to find y from the experimental rate data provided. To simplify the tabulated rate data, we can rewrite the table as small whole number multiples of the smallest entry in each column:

line #	$[A]_o$	$[B]_o$	rate
1	1	1	1
2	2	1	2
3	4	3	36

From the revised rate data we can now determine the reaction orders. Looking at lines 1 and 2, where the concentration of reactant B is held constant, we see that doubling the concentration of A cause the rate to double; therefore the reaction is first order with respect to A. We can now look at lines 1 and 3 to determine the required reaction order. From line 1 to line 3, the concentration of A has increased by a factor of four. We determined that the reaction is first order with respect to A, so if B had not changed, the rate would have increased by a factor of 4. However, the rate increased by a factor of 36. We calculate the change in the rate due to B by dividing out the effect A has on the rate, so then B must have been responsible for an increase of a factor of 9 (36 _ 4). Therefore, since B increased by a factor of 3, and it increased the rate by a factor of 9, the reaction is second order with respect to B ($3^y = 9$; y = 2). This can be represented by creating a hypothetical line 4:

line #	$[A]_o$	$[B]_o$	rate
1	1	1	1
2	2	1	2
3	4	3	36
4	1	3	9

From this revision of the experimental data it can be seen (lines 1 and 4) that tripling [B] results in a 3^2 increase of the rate, i.e., $3^y = 3^2$. Therefore the reaction is second order with respect to B.

3. D

Acid-catalyzed reactions are enhanced by the presence of protons, H^+, which have a 'molecular' weight of 1, while enzymes, which catalyze many biochemical reactions, are usually proteins of high molecular weight, often in excess of 200,000. As for the wrong choices, choice A is incorrect since catalysts operate by lowering the activation energy of a reaction pathway (and thus changing the kinetics of the reaction) without affecting the thermodynamics of the reaction. Choice B is wrong since the lowering of the activation energy must be by the same numerical value in either direction; this leaves the ratio of forward rate to reverse rate, i.e., the equilibrium constant, unchanged. Choice C is incorrect for the same reason as choice B. Finally, choice E is incorrect since catalysts do interact with the reactants during the course of the reaction, else there would be no catalytic effect; catalysts are, however, regenerated at the end of the reaction, and thus there is no net change in the concentration of the catalyst overall.

4. B

To calculate thermodynamic values for a reaction or process we can apply Hess's Law, which states that the total change in a thermodynamic state function (such as enthalpy here) can be found as the sum of the changes for a series of steps with the same net result. Such a series of steps and net result for this particular example, with the _H value for each step, are shown below:

$2\ C(s) + 2\ O_2(g)$ ∅ $2\ CO_2(g)$ 2(–394)
$H_2(g) + O_2(g)$ ∅ $2\ H_2O(l)$ 2(–286)
$2\ CO_2(g) + 3\ H_2O(l)$ ∅ $C_2H_5OH(l) + 3\ O_2(g)$ –(–1367)

$2\ C(s) + 2\ H_2(g) + H_2O(l)$ ∅ $C_2H_5OH(l)$ _H= 2(–394) + 2(–286) – (–1367)

Adding the values to arrive at the net _H, the result is +7 kJ, choice B.

5. C

This is easier than #4 in terms of the number of steps and the calculations involved, but it does require a working definition of $\_H_f$. The heat of formation, $\_H_f$, is defined as the enthalpy change accompanying the reaction, real or hypothetical, of elements in their standard states coming together to form the product in question. Thus in a manner similar to that used in #4, $\_H_f$ can be calculated as:

$H_2(g) + {}^1/_2\ O_2(g)$ ∅ $H_2O(l)$ (–286)
$H_2O(l)$ ∅ $H_2O(g)$ – (–44)

$H_2(g) + {}^1/_2\ O_2(g)$ ∅ $H_2O(g)$ _H = –286 + 44 = –242 kJ

To employ logic (rather than calculation) in this problem, notice that the formation of water can also be thought of as a combustion since it is the reaction of hydrogen with oxygen; it must therefore be exothermic and choices D and E can be dismissed. Further, since energy is required to turn a liquid into a gas, the formation of gaseous water will be less exothermic than the formation of liquid water; the answer must therefore be exothermic, but less exothermic than choice B. This leaves choice C as the only logical choice.

6. D

This potential gas law problem can be solved faster through reasoning rather than through calculations. First, if the temperature is higher while the pressure and number of moles are the same, it follows that gas A must occupy a larger volume than does gas B, so choices A and B can be removed. Secondly, since 30°C is only slightly higher than 20°C when we convert to the (mandatory!) Kelvin scale by adding 273, it follows that the volume of gas A will be only slightly larger than that of gas B. Choice D is thus the only sensible answer. (Note in particular that choice C is provided for those who forget that gas law problems must always be done with temperature on the Kelvin scale.)

To use the gas law, PV = nRT, to solve this problem through calculation we can rearrange to solve for each of the volumes, V_A and V_B, then set up the desired ratio as follows:

$V_A = \frac{n_ART_A}{P_A}$ and $V_B = \frac{n_BRT_B}{P_B}$. We know that $n_A = n_B = 1$ mol, $P_A = P_B = 1$ and R is a constant. Therefore, $V_A : V_B = \dfrac{\frac{n_ART_A}{P_A}}{\frac{n_BRT_B}{P_B}}$. The pressures, moles, and Rs all cancel, leaving $V_A : V_B = \frac{T_A}{T_B} = \frac{(30 + 273)}{(20 + 273)} = \frac{303}{293}$.

7. E

This problem is best answered based on atomic properties and periodic trends. In general, a cation is smaller than a neutral atom of the same element because the removal of electrons decreases the electrostatic repulsion between the remaining electrons, thereby allowing the nucleus to pull them closer, decreasing the ionic radius. Conversely, anions are generally larger than the corresponding neutral atoms because of an increased number of electrons that repel one another. Thus the question can be translated into "Which of the following elements is most likely to form an anion?" This revised stem can be answered on the basis of periodic trends, in particular the trend in electronegativity which increases toward the upper right corner of the table. Chlorine, Cl, is the most electronegative of the elements listed; it would thus be expected to have the greatest electron affinity,

and is thus most likely to take on an electron and become anionic. The four elements in the incorrect choices are all more likely to form cations than anions; their ionic radii will thus be smaller than their atomic radii.

8. D

This question is testing some basic concepts of quantum mechanics. According to the Pauli exclusion principle, no two electrons on a single atom can have an identical set of values for the four quantum numbers n, l, m_l, and m_s. If two electrons occupy the 3*s* orbital then they already have the same values of n (=3), l (=0), and m_l(=0); it is therefore necessary, per Dr. Pauli, that their spin numbers be different, i.e., that they have opposite spins, as stated in choice D. Since there is only one orbital in the 3*s* subshell, choice A is impossible. Choice B grossly distorts the Heisenberg uncertainty principle, which states that one cannot simultaneously determine the momentum and the location of an electron precisely; this principle does not require electrons to absorb energy, as they must to occupy a higher energy subshell. Choice C refers to the oxidation state of the atom which is determined by the total number of electrons attributed to the atom in a compound. This total number of electrons, and the resulting oxidation number, depend on the identity of the element; magnesium, for instance, has an oxidation number of zero when two electrons occupy its 3*s* subshell, while a heavy element like uranium always has two electrons in its 3*s* subshell, regardless of its oxidation state. The final choice, choice E, neglects the simple fact that electrons are always negatively charged.

9. E

Thermodynamics again, meaning that we should be both wary of excessive time spent on calculations and on the lookout for logical shortcuts. As far as logic is concerned, note that we are asked about the _H when SO_2 is 'burned.' The answer should thus be exothermic, i.e., _H is negative, and choices A and C should be removed from consideration. Furthermore, since SO_2 and SO_3 will be one to one in terms of stoichiometry, the answer should be a simple combination of the two numbers given, either a sum or a difference; 3600 + 1300 = 4900 or 3600 - 1300 = 2300. Choice E is thus the most logical choice, as well as the correct answer.

To calculate the answer, Hess's law can once again be invoked:

O_2 ∅ S + O_2 _H = –(–1300 cal)

S + $^3/_2$ O_2 ∅ SO_3 _H = –3600 cal

SO_2 + $^1/_2$ O_2 ∅ SO_3 _H = –2300 cal

10. A

This question is best answered based on atomic properties and periodic trends. In general, electronegativity increases from left to right across a period, and decreases from top to bottom down a group, of the Periodic Table. Since the elements offered in the choices can all be found in the same column of the Periodic Table, it follows that the one at the top, carbon, will be the most electronegative.

11. E

While this can be answered by calculations based on the ideal gas law, once again shortcuts can be applied. Increasing pressure decreases the volume of a gas, while increasing temperature increases the volume. If the pressure doubles, the volume will halve, while tripling the temperature will triple the volume. Thus if both changes are incurred, the volume will be multiplied by 3 <u>and</u> divided by 2 or, in other words, the volume will be multiplied by $^3/_2$. Since the volume of one mole of a gas at STP can be approximated as 22.4 liters, three halves of this volume will be 33.6 liters.

12. E

This question is best answered based on atomic properties and periodic trends. Metallic character is greatest toward the lower left-hand corner of the Periodic Table. Metallic character includes physical properties such as malleability, ductility, and luster, as well as chemical properties such as low ionization energy, electron affinity, and electronegativity. Choices A and B are thus standard physical properties of metals rather than nonmetals. On the other hand, the low ionization energy of metals allows them to easily give up an electron to a willing acceptor; metals are therefore easily oxidized and thus make good reducing agents. The opposite is true of nonmetals, so choices C and D can be eliminated and E is the credited choice. (Note here that choices C and D are equivalent since a good reducing agent is one that is readily oxidized.)

13. C

This question requires us to balance the given equation. Since the first reactant, Mg_3N_2, has 3 atoms of magnesium and 2 atoms of nitrogen, we can begin by putting a 3 in front of the magnesium containing product $Mg(OH)_2$, and a 2 in front of the nitrogen containing product NH_3. We will then have 6 OH groups in the 3 $Mg(OH)_2$'s and 6 H atoms in the 2 NH_3's. Combining these H's and OH's would give us 6 H_2O's, so we can write a 6 in front of H_2O on the reactant side of the equation. The result is thus $Mg_3N_2 + 6\ H_2O \varnothing 3\ Mg(OH)_2 + 2\ NH_3$; a quick recount verifies that the number of each type of atom on each side of the equation does indeed balance. Summing the coefficients then gives us 1 + 6 + 3 + 2 = 12. Note that the coefficient before Mg_3N_2 is 1, not 0!

14. C

This is a limiting reactant problem, recognizable as such since both reactant quantities are given. The maximum quantity of product formed will be determined by the reactant which is used up first as the reaction proceeds; when one reactant is gone, no more product can form, and the reactant which is used up first is thus said to be limiting. For this problem, we are producing water by the reaction of hydrogen and oxygen. The balanced equation is:

$$H_2 + {}^1/_2\ O_2 \varnothing H_2O$$

From the balanced equation, and a little stoichiometry, we can determine simultaneously which reactant is limiting and how much water will be produced:

$$100\text{ g } H_2 \times \frac{1\text{ mol } H_2}{2\text{g } H_2} \times \frac{1\text{ mol } H_2O}{\text{mol } H_2} = 50\text{ mol } H_2O$$

$$100\text{ g } O_2 \times \frac{1\text{ mol } O_2}{32\text{g } O_2} \times \frac{2\text{ mol } H_2O}{\text{mol } O_2} = \frac{100}{32} \times 2\text{ mol } H_2O$$

Since the available oxygen results in a smaller quantity of water, oxygen is the limiting reactant and (100 x 2)/32 moles of water will be formed. This result can be rewritten as 2 x (100/32), or choice C.

15. A

Dalton's law of partial pressures states that the pressure exerted by an ideal gas in a mixture is the same as it would be if the gas were to occupy the same volume alone. If we focus on the neon we can approach this problem as if the volume increases from the initial 300 mL to the combined 500 mL and use the relationship $P_1V_1 = P_2V_2$ (Boyle's law). Note that, qualitatively, we can dismiss choices C, D, and E since an increase in volume will lead to a decrease in pressure and so the answer must be less than 100 mmHg. Completing the calculations:

$$P_2 = P_1V_1/V_2 = (100\text{ mmHg})(300\text{ mL})/(500\text{ mL}) = {}^3/_5(100\text{ mmHg}) = 60\text{ mmHg}.$$

16. D

Elastic collisions are those in which the colliding particles do not stick together and translational kinetic energy is not dissipated, such as those occurring between the particles of an ideal gas. Inelastic collisions do occur in real gases. Choice A is thus true while choice B is false. Choice C is also true; a nuclear fusion reaction is a reaction in which two nuclei collide to form a new, heavier nucleus. Since both choices A and C (and only choices A and C) are true, choice D, 'two of the above' is the credited choice.

17. A

The Kinetic Theory of Gases defines that an ideal gas is composed of particles of negligible volume in constant but random motion, that there are no interactions among these particles, that any collisions are completely elastic, and that the average kinetic energy of the particles is proportional to the absolute temperature. Choice A is thus one of these assumptions, while wrong choices B, C, and D are contrary to other parts of the theory. Choice E is incorrect because it is the temperature rather than the pressure that is an indication of the average kinetic energy.

18. C

Since heat is written as a product in the equation, we know that the reaction is exothermic. An increase in temperature, according to Le Châtelier's principle, will shift the equilibrium toward the left. A shift toward the left implies a decrease in the yield of the product, ammonia; therefore choice C is correct. Choices B and D are incorrect since heat is shown as a product,

indicating that the reaction is exothermic, not endothermic. Choice A is wrong since the yield of ammonia will be decreased, not increased, by the addition of heat to the system. Finally choice E is incorrect since adding heat to the equilibrium mixture will affect the yield of ammonia.

19. C

The hybridization of the central atom in a molecule or ion is easily determined by counting the number of bonds and electron pairs of the central atom and then counting orbitals, in *s-p-d-f* order. An atom with two bonds or electron pairs is *sp* hybridized, one with three bonds or electron pairs is sp^2, etc. The AB_6 species in this question must have six bonds to the central A atom, regardless of charge, one for each B atom or group. The hybridization must therefore utilize six orbitals. Only one of these orbitals can be *s*, the next three must be *p* (for a total of four so far) and the next two must be *d*. One *s* plus three *p* plus two *d* equals six total orbitals, so the hybridization is sp^3d^2, as stated in choice C. Choice A, sp^3 hybridization, occurs when the central atom is bonded to four other atoms; a standard example would be methane, CH_4, in which the central carbon atom is bonded to the four surrounding hydrogen atoms. Choice B, sp^3d, occurs when there are five atoms attached to the central atom; an example of sp^3d hybridization is PCl_5. Choice D, sp^2, is the hybridization of the double bonded carbon atoms in alkenes and ketones, for example, so popular in organic molecules; these sp^2 hybridized carbons are bonded to three other atoms. Similarly, the ketone oxygen is sp^2: while it is bonded to only one atom, it has two lone pairs and thus has three occupied hybrid orbitals. Finally, choice E, sp^2d, is a much less common hybridization. It is found in molecules and ions such as ClO_2^-, where the central chlorine atom has two lone pairs and is bonded to the two oxygen atoms. This ion also has a _ bond which is formed via the side-by-side overlap of the third chlorine *p* orbital with one of the oxygen *p* orbitals. Since this chlorine *p* orbital is already in use, it is necessary for one of the chlorine 3*d* orbitals to participate in the hybridization.

20. E

This problem is based on atomic properties and periodic trends. Transition elements reside in the center, or *d*-block, of the Periodic Table and are often called transition metals because of their metallic character and the fact that many can be found in the metallic form in nature. Most have incomplete *d* subshells, while the next *s* sublevel is occupied. For example, vanadium has the electron configuration V = $[Ar]4s^23d^3$; its 4*s* sublevel is occupied while its 3*d* subshell is incomplete. Choice A, multiple oxidation states, is a characteristic of most transition metals; vanadium for example can lose the 4*s* electrons, the 3*d* electrons, or both to form a 2^+, 3^+ or 5^+ cation respectively. Choice B, incomplete inner shells is also a characteristic of most transition metals as stated above. Choice C refers to the position of these elements within the Periodic Table and is also a true statement, while choice D indicates accurately that heavy metals such as gold and mercury are among their ranks. Choice E is the only inaccurate statement regarding transition metals, since they are not found in the first two rows of the Periodic Table.

21. B

Atomic number 16 corresponds to sulfur, which has an electron configuration of $1s^22s^22p^63s^23p^4$ or $[Ne]3s^23p^4$. All the electrons up through the 3*s* subshell are paired, but the four electrons in the 3*p* subshell must occupy the three available orbitals in this subshell. Since no more than two electrons can occupy a single orbital, we have two electrons which must remain unpaired.

22-25. C/A/C/A

This series of questions is testing the classification of elements based on their positions in the Periodic Table. Choice A, inert gases, are the elements found in the last column of the table. Based on their position, one can predict that these elements will generally have the smallest atomic radii and the largest ionization energy of the elements within a given period, or row, of the Periodic Table. Choice A is thus the correct answer to both question 23 and question 25. (Starting from the fourth period, though, transition elements may have smaller atomic radii because electrons are added to the d orbitals of a lower principal quantum number.) Choice B, active metals, refers to those elements found on the far left side of the table, particularly those in the lower left-hand corner. These elements are relatively large in size, and have low ionization energies, electron affinities, and electronegativities. The active metals are aptly named; they are so reactive that they are found in nature only in cationic form. Choice B is not an answer to any questions in this group. Choice C, transition elements, was discussed in detail back in question number 20 of this practice test; it is the correct answer to both question 22 and question 24 of this set. Choice D, active non-metals, does not apply to any of the questions in this set; these elements are found in the upper right-hand corner of the Periodic Table (but not in the last column) and generally have large electron affinities and electronegativities.

26. C

While we might be tempted to apply the ideal gas law to this problem, this attempt would lead to frustration and wasted time. Simply put, if 3 moles (the stoichiometric quantities referred to) of gaseous reactants produce a pressure of 12 atm, it follows that 1 mole of gaseous product will produce $^{1}/_{3}$ the pressure, or 4 atm, at the same temperature and in the same volume.

As a semi-quantitative approach, we could rearrange the ideal gas law, PV = nRT, into P = n(RT/V) and, noting that R, T, and V are all constant, 'delta' each side, then rearrange:

$\Delta P = \Delta n(RT/V)$ _ $\Delta P/ \Delta n = \text{constant}$

From this semi-quantitative rearrangement we may be more easily able to see that if n triples, then P will triple and so on.

27. A

In this case, the pressure and temperature are held constant and we are asked to find the change in volume as the reaction proceeds. Since complete reaction means that 3 moles becomes 1 mole, and since volume is proportional to the number of moles (Avogadro's law), it follows that the volume will be one third as large after the reaction as it was before the reaction. Thus 30 liters becomes 10 liters, and choice A is indeed correct.

28. B

Atomic radius decreases from left to right across a period and increases from top to bottom down a group on the Periodic Table; electronegativity increases from left to right across a period and decreases from top to bottom down a group. As such, these two trends are antiparallel; as one moves down a group, such as Group VIIA, the atomic radius will increase while the electronegativity decreases.

29. D

The percent by mass of an element in a compound is calculated by multiplying the atomic mass of that element by the number of atoms of that element in one formula of the compound, then dividing by the total formula weight of the compound and, finally, converting the result to a percentage. (Any necessary atomic masses can be found on the Periodic Table and thus do NOT need to be memorized.) In this example, the percent by mass is given, while the empirical formula must be found; for complete calculation, the process must therefore be reversed. Since we do not know the formula weight, we must make an assumption; it is usually most convenient to assume a 100 gram sample is analyzed, so that the percentages convert directly into grams. In this example we would thus wind up with 12.5 grams of hydrogen, 37.5 grams of carbon, and 50 grams of oxygen. The mass in grams is then converted to the relative number of moles of each element, from which the formula can then be determined:

12.5 g H/(1.0 g/mol) = 12.5 moles H
37.5 g C/(12 g/mol) = 3.125 moles C
50 g O/(16 g/mol) = 3.125 moles O

12.5 moles H/ 3.125 moles C = 4 moles H/mole C
3.125 moles O/ 3.125 moles C = 1 mole O/mole C

The result is thus CH_4O.

Obviously there must be a shortcut to a problem of this length. It would be much faster, for instance, to simply approximate one percentage from each of the answer choices and see which one matches the percentages given in the stem. Let us do just that, using the percent by mass of oxygen, since it is the roundest percentage:

A. FW = 12 + 1 + 16 = 29. $^{16}/_{29}$ is NOT $^{1}/_{2}$.
B. FW = 12 + 2 + 16 = 30. $^{16}/_{30}$ is NOT $^{1}/_{2}$.
C. FW = 12 + 3 + 16 = 31. $^{16}/_{31}$ is NOT $^{1}/_{2}$.
D. FW = 12 + 4 + 16 = 32. $^{16}/_{32}$ is $^{1}/_{2}$.
E. FW = 24 + 4 + 16 = 44. $^{16}/_{44}$ is NOT $^{1}/_{2}$.

30. D

Elements in the same group, or column of the Periodic Table, have similar chemical properties due to the similarity in their electron configurations. Of the choices offered, only choice D, K and Na, consists of two elements in the same group (Group IA, the alkali metals). These two elements are active metals, and form only cations with a +1 oxidation number when reacted with halogens, alcohols, or water. They react with elemental oxygen, for example, to form oxides of the general

formula M_2O, and these oxides can then react with water to form hydroxides of the general formula MOH. The other choices offer pairs of elements which are somewhat similar in chemical properties, but not as similar as those in the credited choice. Choice A lists two active metals, Mg and K, which are similar in that they are both high in metallic character, but differ in that potassium is much more active and forms a +1 cation, while the less active magnesium forms a +2 cation. Choice B, O and N, contains two nonmetals which normally exist as diatomic gases. They differ in chemical behavior because they have different oxidation states when combined into compounds. The two entries in choice C, Au and Pt, are both relatively inactive heavy metals, but differ once again in their preferred oxidation states: gold forms ionic compounds in which it has either a +1 or a +3 charge, while platinum is most likely to be found in either the +2 or +4 state. Finally, choice E consists of two more relatively inert metals, Cu and Pb. The valence electron configuration of copper, $4s^1 3d^{10}$, allows it to easily form either +1 or +2 cations ($4s^0 3d^{10}$ or $4s^2 3d^8$, respectively). The valence configuration of lead ($6s^2 5d^{10} 6p^2$) leads easily only to the +2 state($6s^2 5d^{10} 6p^0$), and with more difficulty to the +4 state($6s^0 5d^{10} 6p^0$).