Multiple Choice (Only one correct answer for each question.) 2 points for each question.

1. An element's most stable ion forms an ionic compound with chlorine having the formula XCl_2. If the mass number of the ion is 40 and it has 18 electrons, what is the element and how many neutrons does it have?
   (A) Ar, 22 neutrons (B) Ar, 24 neutrons (C) S, 24 neutrons (D) Ca, 20 neutrons (E) K, 19 neutrons

2. A material is made from Al, Ga, and As. The mole fractions of these elements are 0.25, 0.26, and 0.49, respectively. This material would be
   (A) a metallic conductor because Al is present. (B) an insulator. (C) a *p*-type semiconductor.
   (D) an *n*-type semiconductor. (E) superconductor.

3. How many protons, neutrons, and electrons does the atom ^{33}S have?
   (A) 16 protons, 16 neutrons, 33 electrons (B) 17 protons, 17 neutrons, 16 electrons
   (C) 16 protons, 16 neutrons, 16 electrons (D) 17 protons, 16 neutrons, 17 electrons
   (E) 16 protons, 17 neutrons, 16 electrons

4. A certain substance, X, has a triple-point temperature of 20°C at a pressure of 2.0 atm. Which one of the following statements cannot possibly be true?
   (A) X can exist as a liquid above 20°C. (B) X can exist as a solid above 20°C.
   (C) Liquid X can exist as a stable phase at 25°C, 1 atm. (D) Both liquid and solid X have the same vapor pressure at 20°C.
   (E) All of these statements could be true.

5. Iron is biologically important in the transport of oxygen by red blood cells from the lungs to the various organs of the body. In the blood of an adult human, there are approximately 2.60×10^{13} red blood cells with a total of 2.90 g of iron. On the average, how many iron atoms are present in each red blood cell? (molar mass for Fe = 55.85 g)
   (A) 8.33×10^{-10} (B) 1.20×10^{9} (C) 3.12×10^{22} (D) 2.60×10^{13} (E) 5.19×10^{-2}

6. A liquid-liquid solution is called an ideal solution if
   I. it obeys $PV = nRT$. II. it obeys Raoult's law.
   III. solute-solute, solvent-solvent, and solute-solvent interactions are very similar.
   IV. solute-solute, solvent-solvent, and solute-solvent interactions are quite different.
   (A) I, II, III (B) I, II, IV (C) II, III (D) II, IV (E) I, II

7. To calculate the concentration in molarity of a salt solution, you need to know
   (A) the mass of the salt added to the solution and the volume of water added to the solution.
   (B) the mass of the salt added to the solution and the total volume of the solution.
   (C) the mass of the salt added, the molar mass of the salt, and the total volume of the solution.
   (D) the molar mass of the salt and the total volume of the solution.
   (E) the mass of the salt added, the molar mass of the salt, the volume of water added, and the total volume of the solution.

8. Which pair of ions would *not* be expected to form a precipitate when dilute solutions of each are mixed?
   (A) Cu^{2+}, S^{2-} (B) Ag^{+}, Cl^{-} (C) Ca^{2+}, PO_4^{3-} (D) Mn^{2+}, OH^{-} (E) Mg^{2+}, SO_4^{2-}

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9. The molar mass of a solid as determined by freezing-point depression is 10% higher than the true molar mass. Which of the following experimental errors could *not* account for this discrepancy?
(A) Not all the solid was dissolved. (B) More than the recorded amount of solvent was pipetted into the solution.
(C) The solid dissociated slightly into two particles when it dissolved. (D) Some solid was left on the weighing paper.
(E) Before the solution was prepared, the container was rinsed with solvent and not dried.

Use the following to answer questions 10-11:
A plastic bag is weighed and then filled successively with two gases, X and Y. The following data are gathered:
Temperature: 0.0°C, Pressure: 1.00 atm, Mass of empty bag: 20.77 g, Mass of bag filled with gas X: 24.97 g, Mass of 1.12 L of air at conditions given: 1.30 g, Volume of bag: 1.12 L, Molar volume at STP: 22.4 L

10. The mass of 1.12 L of gas Y is found to be 6.23 g. The density of gas Y is
(A) 10.6 g/L. (B) 5.56 g/L. (C) 15.6 g/L. (D) 0.200 g/L. (E) 0.180 g/L.

11. The molar mass of gas Y is
(A) 56.0 g/mol. (B) 89.0 g/mol. (C) 125 g/mol. (D) 140. g/mol. (E) 157 g/mol.

12. Under which of the following conditions does a gas behave most ideally?
(A) STP (B) $P = 1.0$ atm, $T = 100.0°C$ (C) $P = 0.50$ atm, $T = 100.0°C$ (D) $P = 0.50$ atm, $T = 0.0°C$
(E) $P = 2.0$ atm, $T = -100.0°C$

13. Which of the following statements concerning equilibrium is *not* true?
(A) A system that is disturbed from an equilibrium condition responds in such a way as to restore equilibrium.
(B) Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
(C) The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
(D) A system moves spontaneously toward a state of equilibrium.
(E) The equilibrium constant is independent of temperature.

14. For the reaction $2\ H_2(g) + O_2(g) \rightleftharpoons 2\ H_2O(g)$, what is the relationship between K and K_p at temperature T?
(A) $K = K_p$ (B) $K = K_p(RT)^2$ (C) $K_p = K(RT)^2$ (D) $K = K_p(RT)$ (E) $K_p = K(RT)$

15. For a particular system at a particular temperature, there are _____ equilibrium constant(s) and _____ equilibrium position(s).
(A) an infinite number of, one (B) one, an infinite number of (C) one, one
(D) an infinite number of, an infinite number of (E) none of these

16. Which of the following statements about the equilibrium is *false*?
(A) If the system is heated, the right side is favored.
(B) This is a heterogeneous equilibrium.
(C) If the pressure on the system is increased by changing the volume, the left side is favored.
(D) Adding more $H_2(g)$ increases the equilibrium constant.
(E) Removing HI as it forms forces the equilibrium to the right.

17. Which of the following species is *not* amphoteric?
(A) HSO_4^- (B) $H_2PO_4^-$ (C) HPO_4^{2-} (D) H_2O (E) HS^-

18. The following acids are listed in order of decreasing acid strength in water.
$HI > HNO_2 > CH_3COOH > HClO > HCN$

According to Brønsted-Lowry theory, which of the following ions is the weakest base?

(A) I^- (B) NO_2^- (C) CH_3COO^- (D) ClO^- (E) CN^-

19. In deciding which of two acids is the stronger, one must know

(A) the concentration of each acid solution only. (B) the pH of each acid solution only.

(C) the equilibrium constant of each acid only. (D) all of these.

(E) both the concentration and the equilibrium constant of each acid.

20. Which of the following indicates the most acidic solution?

(A) $[OH^-] = 0.5\ M$ (B) $[H^+] = 0.3\ M$ (C) $p\text{OH} = 5.9$ (D) $p\text{H} = 1.2$ (E) $[H^+] = 1.0 \times 10^{-4}\ M$

21. You are given a solution of the weak base Novocain, Nvc. Its pH is 11.00. You add to the solution a small amount of a salt containing the conjugate acid of Novocain, $NvcH^+$. Which statement is true?

(A) The *p*H and the *p*OH both increase. (B) The *p*H and the *p*OH both decrease.

(C) The *p*H and the *p*OH remain unchanged. (D) The *p*H increases and *p*OH decreases.

(E) The *p*H decreases and the *p*OH increases.

22. Consider a solution of 2.0 *M* HCN and 1.0 *M* NaCN (K_a for HCN = 6.2×10^{-10}). Which of the following statements is true?

(A) The solution is not a buffer because [HCN] is not equal to $[CN^-]$.

(B) The *p*H will be below 7.00 because the concentration of the acid is greater than that of the base.

(C) $[OH^-] > [H^+]$

(D) The buffer will be more resistant to *p*H changes from addition of strong acid than to pH changes from addition of strong base.

(E) The *p*H will be equal to 7.00.

23. Suppose you add 45 J of heat to a system, let it do 10 J of expansion work, and then return the system to its initial state by cooling and compression. Which statement is true for this process?

(A) $\Delta H < \Delta E$

(B) The work done in compressing the system must exactly equal the work done by the system in the expansion step.

(C) $\Delta H = 70$ J (D) The change in the internal energy for this process is zero. (E) $\Delta H = 35$ J

24. $C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(l)$, $\Delta H = -1.37 \times 10^3$ kJ

For the combustion of ethyl alcohol as described in the above equation, which of the following statements is(are) true?

I. The reaction is exothermic.

II. The enthalpy change would be different if gaseous water were produced.

III. The reaction is not an oxidation–reduction one.

IV. The products of the reaction occupy a larger volume than the reactants.

(A) I, II (B) I, II, III (C) I, III, IV (D) III, IV (E) I only

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25. Which statement is true of a process in which 1 mol of a gas is expanded from state A to state B?

(A) When the gas expands from state A to state B, the surroundings are doing work on the system.

(B) The amount of work done in the process must be the same, regardless of the path.

(C) It is not possible to have more than one path for a change of state.

(D) The final volume of the gas will depend on the path taken.

(E) The amount of heat released in the process will depend on the path taken.

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Use the following to answer questions 26 and 27:
Two samples of a monatomic ideal gas are in separate containers at the same conditions of pressure, volume, and temperature (V = 1.00 L and P = 1.00 atm). Both samples undergo changes in conditions and finish with V = 2.00 L and P = 2.00 atm. However, in the first sample, the volume is changed to 2.0 L while the pressure is kept constant, and then the pressure is increased to 2.00 atm while the volume remains constant. In the second sample, the opposite is done. The pressure is increased first, with constant volume, and then the volume is increased under constant pressure.

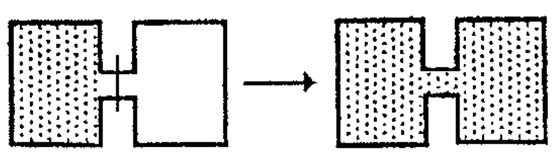
26. Calculate the difference in ΔE between the first sample and the second sample.
(A) 0 (B) 1.00 L•atm (C) 2.00 L•atm (D) 3.00 L•atm (E) 4.50 L•atm

27. Calculate the difference in q between the first sample and the second sample.
(A) -2.00 L•atm (B) -1.00 L•atm (C) 1.00 L•atm (D) 2.00 L•atm (E) 0.00 L•atm

28. When a student performs an endothermic reaction in a calorimeter, how (if any) does the calculated value of ΔH differ from the actual value if the heat exchanged with the calorimeter is not taken into account?
(A) ΔH_{calc} is more negative because the calorimeter always absorbs heat from the reaction.
(B) ΔH_{calc} is less negative because the calorimeter absorbs heat from the reaction.
(C) ΔH_{calc} is more positive because the reaction absorbs heat from the calorimeter.
(D) ΔH_{calc} is less positive because the reaction absorbs heat from the calorimeter.
(E) ΔH_{calc} equals the actual value because the calorimeter does not absorb heat.

29. A mixture of hydrogen and chlorine remains unreacted until it is exposed to ultraviolet light from a burning magnesium strip. Then the following reaction occurs very rapidly.
$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$ $\Delta G = -45.54$ kJ, $\Delta H = -44.12$ kJ, $\Delta S = -4.76$ kJ,
Select the statement below that best explains this behavior.
(A) The reactants are thermodynamically more stable than the products.
(B) The reaction has a small equilibrium constant.
(C) The ultraviolet light raises the temperature of the system and makes the reaction more favorable.
(D) The negative value for ΔS slows down the reaction.
(E) The reaction is spontaneous, but the reactants are kinetically stable.

30. Which of the following result(s) in an increase in the entropy of the system?

I. 

I. (See diagram.) II. $Br_2(g) \rightarrow Br_2(l)$ III. $NaBr(s) \rightarrow Na^+(aq) + Br^-(aq)$ IV. $O_2(298\ K) \rightarrow O_2(373\ K)$
V. $NH_3(1\ atm, 298\ K) \rightarrow NH_3(3\ atm, 298\ K)$
(A) I (B) II, V (C) I, III, IV (D) I, II, III, IV (E) I, II, III, V

31. One mole of an ideal gas at 25°C is expanded isothermally from 5.0 L to 10.0 L under such conditions that no work is produced in the surroundings. Which statement is correct?
(A) $\Delta S_{gas} = 0$ (B) $\Delta S_{gas} = R\ln 2/298$ (C) $\Delta S_{univ} = 0$ (D) $\Delta S_{surr} = 0$ (E) $\Delta S_{gas} = \Delta S_{surr}$

32. For which process is ΔS negative?
(A) evaporation of 1 mol of $CCl_4(l)$ (B) mixing 5 mL of ethanol with 25 mL of water
(C) compressing 1 mol of Ne at constant temperature from 1.5 atm to 0.5 atm
(D) raising the temperature of 100 g of Cu from 275 K to 295 K (E) grinding a large crystal of KCl to powder

33. When a stable diatomic molecule spontaneously forms from its atoms, what are the signs of $\Delta H°$, $\Delta S°$, and $\Delta G°$, respectively?

(A) + + + (B) + − − (C) − + + (D) − − + (E) − − −

34. For the reaction A + B → C + D, $\Delta H°$ = +40 kJ and $\Delta S°$ = +50 J/K. Therefore, the reaction under standard conditions is

(A) spontaneous at temperatures less than 10 K. (B) spontaneous at temperatures greater than 800 K.

(C) spontaneous only at temperatures between 10 K and 800 K. (D) spontaneous at all temperatures.

(E) nonspontaneous at all temperatures.

35. A strip of copper is placed in a 1 *M* solution of copper nitrate, and a strip of silver is placed in a 1 *M* solution of silver nitrate. The two metal strips are connected to a voltmeter by wires, and a salt bridge connects the solutions. The following standard reduction potentials apply:

$Ag^+(aq) + e^- \rightarrow Ag(s)$ $E° = +0.80$ V

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E° = +0.34$ V

When the voltmeter is removed and the two electrodes are connected by a wire, which of the following does *not* take place?

(A) Electrons flow in the external circuit from the copper electrode to the silver electrode.

(B) The silver electrode increases in mass as the cell operates.

(C) There is a net general movement of silver ions through the salt bridge to the copper half-cell.

(D) Negative ions pass through the salt bridge from the silver half-cell to the copper half-cell.

(E) Some positive copper ions pass through the salt bridge from the copper half-cell to the silver half-cell.

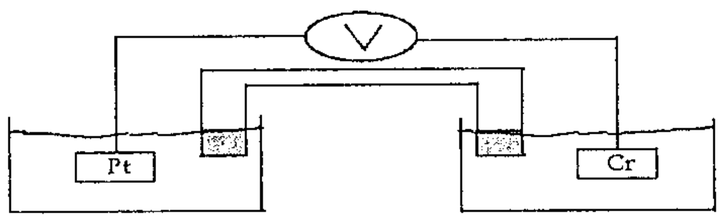
Use the following to answer questions 36-37:

Consider the galvanic cell shown below (the contents of each half-cell are written beneath each compartment).

The standard reduction potentials are as follows:

$Cr^{3+} + 3\ e^- \rightarrow Cr(s)$ $E° = -0.73$ V

$Br_2(aq) + 2\ e^- \rightarrow 2Br^-$ $E° = +1.09$ V



36. What is $E°$ for this cell?

(A) 1.82 (B) 0.36 V (C) 4.75 V (D) 1.79 V (E) 4.40 V

37. Which of the following statements about this cell is *false*?

(A) This is a galvanic cell. (B) Electrons flow from the Pt electrode to the Cr electrode.

(C) Reduction occurs at the Pt electrode. (D) The cell is not at standard conditions.

(E) To complete the circuit, cations migrate into the left half-cell and anions migrate into the right half-cell from the salt bridge.

38. For a reaction in a voltaic cell, both $\Delta H°$ and $\Delta S°$ are positive. Which of the following statements is true?

(A) $E°_{cell}$ will increase with an increase in temperature. (B) $E°_{cell}$ will decrease with an increase in temperature.

(C) $E°_{cell}$ will not change when the temperature increases. (D) $\Delta G° > 0$ for all temperatures.

(E) None of the above statements is true.

39. Which of the following statements is(are) true?

I. An excited atom can return to its ground state by absorbing electromagnetic radiation.

II. The energy of an atom is increased when electromagnetic radiation is emitted from it.

III. The energy of electromagnetic radiation increases as its frequency increases.
IV. An electron in the $n = 4$ state in the hydrogen atom can go to the $n = 2$ state by emitting electromagnetic radiation at the appropriate frequency.
V. The frequency and wavelength of electromagnetic radiation are inversely proportional to each other.
(A) II, III, IV (B) III, V (C) I, II, III (D) III, IV, V (E) I, II, IV

40. Which of the following is a reasonable criticism of the Bohr model of the atom?
(A) It makes no attempt to explain why the negative electron does not eventually fall into the positive nucleus.
(B) It does not adequately predict the line spectrum of hydrogen.
(C) It does not adequately predict the ionization energy of the valence electron(s) for elements other than hydrogen.
(D) It does not adequately predict the ionization energy of the first-energy-level electrons for elements other than hydrogen.
(E) It shows the electrons to exist outside of the nucleus.

41. An electron in a 10.0-nm one-dimensional box is excited from the ground state into a higher energy state by absorbing a photon with wavelength 1.374×10^{-5} m. Determine the final energy level for this transition.
(A) $n = 2$ (B) $n = 3$ (C) $n = 4$ (D) $n = 5$ (E) $n = 6$

42. For an electron in a one-dimensional box, what is the minimum energy to excite the electron from the ground state?
(A) $\frac{h^2}{8\,mL^2}$ (B) $\frac{2h^2}{8\,mL^2}$ (C) $\frac{3h^2}{8\,mL^2}$ (D) $\frac{4h^2}{8\,mL^2}$ (E) $\frac{5h^2}{8\,mL^2}$

43. Which of the following statements is *false*?
(A) An orbital can accommodate at most two electrons.
(B) The electron density at a point is proportional to ψ^2 at that point.
(C) The spin quantum number of an electron must be either +1/2 or –1/2.
(D) A 2p orbital is more penetrating than a 2s; that is, it has a higher electron density near the nucleus and inside the charge cloud of a 1s orbital.
(E) In the usual order of filling, the 6s orbital is filled before the 4f orbital.

44. For which of the following elements does the electron configuration for the lowest energy state show a partially filled d orbital?
(A) V (B) K (C) Cu (D) Ga (E) Ar

45. Which of the following bonds would be the most polar without being considered ionic?
(A) Mg-O (B) C-O (C) O-O (D) Si-O (E) N-O

46. Which of the following ionic compounds has the largest lattice energy; that is, which has the lattice energy most favorable to a stable lattice?
(A) CsI (B) LiI (C) LiF (D) CsF (E) MgO

47. Order the following from shortest to longest bond:
C_2, B_2, H_2, N_2
(A) H_2, N_2, C_2, B_2 (B) N_2, C_2, B_2, H_2 (C) C_2, N_2, H_2, B_2 (D) C_2, B_2, H_2, N_2 (E) H_2, B_2, C_2, N_2

48. For how many of the following does the bond order decrease if you add one electron to the neutral molecule?
B_2, Si_2, P_2, F_2
(A) 0 (B) 1 (C) 2 (D) 3 (E) 4

49. Which of the following electron distributions among the molecular orbitals best describes the NO molecule?

	σ_{2s}	σ_{2s}^*	$\pi_{2py} = \pi_{2px}$	σ_{2pz}	$\pi_{2py}^* = \pi_{2px}^*$	σ_{2pz}^*
I.	2	2	4	2	4	2
II.	2	2	4	2	4	1
III.	2	2	4	1	3	0
IV.	2	2	4	2	2	0
V.	2	2	4	2	1	0

(A) I (B) II (C) III (D) IV (E) V

50. Which one of the following statements about solid Cu (face-centered cubic unit cell) is *incorrect*?

(A) It will conduct electricity. (B) There are two atoms per unit cell.

(C) The number of atoms surrounding each Cu atom is 12. (D) The solid has a cubic closest-packed structure.

(E) The length of a face diagonal is four times the Cu radius.