Name: _____

Final Exam Review Period: ___

(1) Consider the following equilibrium: $CO_2\ (g) + H_2\ (g) + 41\ kJ/mol \rightleftharpoons H_2O\ (g) + CO\ (g)$

(a) What is the effect on the equilibrium of the given stresses?

(i) Temperature is increased.
(ii) $[CO_2]$ is decreased
(iii) $[H_2]$ is increased
(iv) Pressure is increased.

(b) At 1200 K, the above equilibrium has K = 1.4. How would the value of K compare at a temperature of 500 K?

(c) The equilibrium $C\ (s) + H_2O\ (g) \rightleftharpoons CO\ (g) + H_2\ (g)$ has K = 10.

Determine the equilibrium constant for the reaction $C\ (s) + CO_2\ (g) \rightleftharpoons 2CO\ (g)$.

(d) What would the equilibrium constant be for the reaction $CO\ (g) \rightleftharpoons \frac{1}{2}\ C\ (s) + \frac{1}{2}\ CO_2\ (g)$

(2) At high temperatures, $SbCl_5$ gas decomposes according to the following reaction: $SbCl_5\ (g) \rightleftharpoons SbCl_3\ (g) + Cl_2\ (g)$

(a) What is the effect on the equilibrium of the given stresses?

(i) Volume is increased
(ii) Pressure is increased.
(iii) $[Cl_2]$ is increased
(iv) $[SbCl_3]$ is decreased.

(b) An 89.7 g sample of $SbCl_5$ is placed in a 15.0 L container at 182 ºC. Determine the initial pressure of $SbCl_5$.

(c) At equilibrium, the partial pressure of $SbCl_3$ is 0.218 atm. Determine K_p for the equilibrium (give the units).

(d) Calculate K_c for the equilibrium (give the units).

(3) Lead (II) chromate, $PbCrO_4$, has $K_{sp} = 2.0 \times 10^{-16}$.

(a) Give the solubility equilibrium reaction.

(b) Show the K_{sp} expression for this reaction.

(c) Calculate the molar concentration of chromate ions in a saturated solution.

(d) Determine the mass of lead (II) chromate that will dissolve in 100 mL water in order to form a saturated solution. What is the concentration of chromate ions in this solution?

(e) If 4.0 mL of 0.0040 M lead (II) nitrate is mixed with 2.0 mL of 0.0020 M sodium chromate, determine if a precipitate will form. Calculate the concentration of Pb^{2+} and CrO_4^{2-} ions in the solution.

(4) Propanoic acid, $HC_3H_5O_2$, ionizes in water according to the following equation:

$$HC_3H_5O_2\ (aq) + H_2O\ (l) \rightleftharpoons C_3H_5O_2^-\ (aq) + H_3O^+\ (aq) \qquad K_a = 1.34 \times 10^{-5}$$

(a) Write the equilibrium constant expression for the reaction.

(b) Determine the pH of a 0.100 M solution of propanoic acid.

(c) A 100.0 mL sample of 0.100 M propanoic acid solution is titrated with 0.100 M sodium hydroxide solution. Write the net ionic equation for the reaction between propanoic acid and sodium hydroxide. Calculate the volume of sodium hydroxide required to reach the equivalence point.

(d) Calculate the pH of the solution at each of the given intervals of the experiment.

(i) 25.00 mL of sodium hydroxide added.
(ii) 100.0 mL of sodium hydroxide added.
(iii) 125.0 mL of sodium hydroxide added.

(e) A buffer is prepared by adding 0.550 g of solid sodium propanoate ($NaC_3H_5O_2$) to 100 mL of 0.100 M propanoic acid solution.

(i) Calculate the pH of the buffer. Assume the volume of the solution does not change.
(ii) Give the balanced chemical equation for the reaction that occurs when a strong base is added to the buffer.
(iii) Give the balanced chemical equation for the reaction that occurs when a strong acid is added to the buffer.

(5) Predict whether 0.10 M solutions of each of the following salts will be acidic, basic, or neutral. Give a reaction to justify your answer.

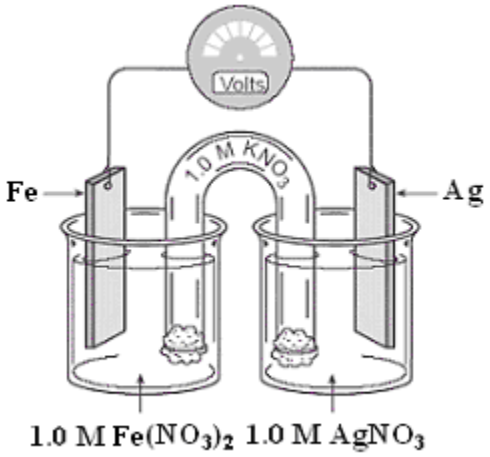
(a) NH_4Cl (b) K_2CO_3 (c) NaBr

(6) (a) Write the balanced equation for the following redox reaction in acidic solution: $Ti^{3+} + HOBr \rightarrow TiO^{2+} + Br^-$

(b) Which element undergoes oxidation and which element undergoes reduction?

(c) Identify the oxidizing agent and the reducing agent for this reaction.

(7) Consider the following electrochemical cell:



(a) Write the cathode half reaction. Label the cathode.
(b) Write the anode half reaction. Label the anode.
(c) Write the overall reaction.
(d) Calculate the cell voltage. (E^o_{cell})
(e) On the diagram, show the direction of electron flow and ion migration.
(f) Which electrode loses mass and which electrode gains mass?
(g) Give the line notation for this electrochemical cell.
(h) Calculate the ΔG^o (in kJ) for this electrochemical cell.
(i) Determine K for this electrochemical cell at 298 K.
(j) The electrochemical cell operates until $[Fe^{2+}] = 1.20$ M
  (i) Calculate $[Ag^+]$

  (ii) Calculate the reaction quotient, Q

  (iii) Compare the cell potential under these conditions to the standard cell potential.
    E_{cell} E^o_{cell}

(k) In similar electrochemical cell, the half-cell containing iron (II) nitrate is diluted such that $[Fe^{2+}] = 0.40$ M. The half cell containing silver nitrate is not changed.
  (i) Calculate the reaction quotient, Q

  (ii) Compare the cell potential under these conditions to the standard cell potential.
    E_{cell} E^o_{cell}

(8) Magnesium can be burned in oxygen in order to produce magnesium oxide according to the following balanced chemical equation:

$$Mg\ (s) + \frac{1}{2}\ O_2\ (g) \rightarrow MgO\ (s)$$

(a) Use the information below to determine the enthalpy for this reaction.

$Mg\ (s) + HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$ $\Delta H^o = -634$ kJ/mol
$MgO\ (s) + HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2O\ (l)$ $\Delta H^o = -318$ kJ/mol
$H_2\ (g) + \frac{1}{2}\ O_2\ (g) \rightarrow H_2O\ (l)$ $\Delta H^o = -286$ kJ/mol

(b) The above reaction has $\Delta S^o = -108.5$ J/mol K. Use the given information to determine the standard entropy for MgO.

Substance	ΔS^o (J/mol K)
Mg (s)	33
O_2 (g)	205

(c) Determine ΔG^o for the above reaction at 298 K. Which is more responsible for the spontaneity of the reaction at this temperature, enthalpy or entropy? Explain.

(9) $Cl_2\ (g) + 3F_2\ (g) \rightarrow 2ClF_3\ (g)$ $\Delta H° = -326.4$ kJmol^{-1}, $\Delta S° = -268.0$ J mol^{-1} K^{-1}
(a) Calculate the amount of heat released to form 75.0 g of ClF_3 (g).
(b) (i) For the reaction at 25 °C, calculate the standard free energy, $\Delta G°$. Is the reaction thermodynamically favoured?
  (ii) Which is more responsible for the spontaneity of reaction, enthalpy or entropy? Explain
  (Iii) Calculate the value of the equilibrium constant, K, for the reaction at 25 °C.
  (iv) Calculate the temperature above which the reaction will be non-spontaneous.
(c) Use the data in the table below to calculate the bond energy in kJ mol^{-1}, of the chlorine-fluorine bond in ClF_3.
  (Show Lewis structures to support your answer)

	Bond Energy (kJ mol^{-1})
Cl–Cl	239
F–F	154
Cl–F	?

(10) Consider the following reaction: $2ClO_2\ (g) + F_2\ (g) \rightarrow 2ClO_2F\ (g)$

Experiment	Initial $[ClO_2]$ (mol/L)	Initial $[F_2]$ (mol/L)	Initial Rate of formation of ClO_2F (mol/Ls)
1	0.010	0.10	0.0024
2	0.010	0.40	0.0096
3	0.020	0.20	0.0096

(a) Determine the order of the reaction with respect to each reactant.
(b) Determine the value of the rate constant, k, and specify units.
(c) Write a rate law for the reaction. What is the overall order of the reaction?
(d) Calculate the initial rate if initial $[ClO_2] = 0.020$ M and initial $[F_2] = 0.40$ M.
(e) Calculate the initial rate of disappearance of F_2 (g) in experiment 1.

(f) The following mechanism is proposed for the reaction:

Step I. $ClO_2 + F_2 \rightarrow ClO_2F_2$
Step II. $ClO_2F_2 \rightarrow ClO_2F + F$
Step III. $ClO_2 + F \rightarrow ClO_2F$

(i) Show that this mechanism gives the overall reaction above.
(ii) Identify the rate-determining step in the mechanism. Explain.
(iii) Sketch a potential energy diagram (given that the overall reaction is exothermic). Label the rate determining step.

(11) Iodine-131 is unstable isotope that decays by emitting a beta particle.
(a) Write an equation for this reaction.
(b) The half-life for the decay of iodine-131 is 8.02 days. (i) What is the order of the reaction? (ii) What is the rate constant for this process?
(c) How long would it take for the sample to decay to 15.0% of the original amount?
(d) What would be the percent remaining after 30.0 days?

(12) (a) (i) Give the orbital notation for the element oxygen (O).
(ii) Give the electron configuration for the element zinc (Zn).
(iii) Classify each of these elements as diamagnetic or paramagnetic. Which of them would be attracted to a magnetic field?
(b) (i) Aluminum has an ionization energy of 576 kJ/mol. How much energy is required to remove a single electron? What is the frequency and wavelength (in nm) of light required?
(ii) For what successive ionization of aluminum would the largest increase in energy be seen?
(iii) The atomic radius for aluminum is 143 pm. Element X has an atomic radius of 90 pm and an ionization energy of 801 kJ/mol and Element Z has an atomic radius of 186 pm and an ionization energy of 496 kJ/mol.
The elements X and Z are each either boron or sodium. Match the unknown elements.
(iv) Would element X or element Z be expected to have a higher electronegativity?

(13) (a) Draw the Lewis structure for the molecules represented below.

BF_3 SF_4 SF_5^- SF_3^+

Calculate the formal charge on each atom for the ions.

(b) (i) Give the bond angle in the compound BF_3.
(ii) Is SF_4 as polar or non-polar? Explain.
(iii) What is the VSPER shape of SF_5^-?
(iv) What is the hybridization of the S atom in SF_3^+?

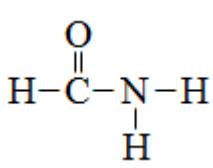
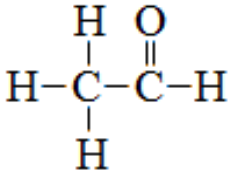
(14) (a) Consider the compounds CF_4 and CBr_4. The bond length of the C-F bond in CF_4 is 134 picometers. Is the C-Br bond in CBr_4 expected to be longer or shorter? Explain. The bond energy of the C-F bond in CF_4 is 135 kJ/mol. Is the C-Br bond in CBr_4 expected to be higher or lower in energy?
(b) Draw a Lewis structure for the compounds O_2 and H_2O_2. Which of the compounds is expected to have an oygen–oxygen bond that is higher in energy? Explain

(15) (a) Classify the Type of solid for each of the following: diamond, copper, calcium chloride, sucrose. List several likely properties for each solid.
(b) Rank the compounds NaF, CsCl, and BaO from lowest to highest melting point. Explain.
(c) Consider the following metals:

Element	Atomic Radius (pm)
Gold	174
Nickel	124
Chromium	128

(i) A common alloy used to make "white gold" consists of 90% gold and 10% nickel. Why would this alloy be expected to be strong and hard?
(ii) An alloy called "nichrome" which consists of 80% nickel and 20% chromium is often used in the production of wires. Why would this alloy be ductile and malleable? The density of nickel is 8.91 g/cm^3 and the density of chromium is 7.19 g/cm^3. Describe the density of nichrome.

(16) Compare the liquids methanamide and ethanal.
(a) List the intermolecular forces for each liquid.

Molecule	Methanamide	Ethanal
Structure		
Intermolecular Forces		
Boiling Point (ºC)		
Vapour Pressure (at 20 ºC)		

(b) One of the liquids has a boiling point of 210 ºC, the other has a boiling point of 20.2 ºC. Match each liquid with the correct value.
(c) At 20 ºC, one of the liquids has a vapour pressure of 600 mm Hg, the other has a vapour pressure of 0.08 mm Hg. Match each liquid with the correct value.
(d) What experimental procedure could be used to separate these liquids in a mixture?

(17) Solid magnesium is combined with hydrochloric acid to produce hydrogen gas and magnesium chloride. The hydrogen gas is collected over water. The volume of the sample was 190.0 mL at 26 ºC. The vapour pressure of water at 26 ºC is 25.2 mm Hg and the total pressure is 754.0 mm Hg.
(a) Calculate the moles of hydrogen produced in the reaction.
(b) Calculate the mass of magnesium that reacted.

(18) An unknown compound is known to contain carbon, hydrogen, and oxygen. A 0.500 g sample is burned in excess oxygen and produces 0.300 g of water and 0.421 L of carbon dioxide at 1.00 atm and 35 ºC.
(a) Determine the mass of hydrogen, carbon, and oxygen in the sample.
(b) Determine the empirical formula of the compound.
(c) The density of the compound at 1.00 atm and 35ºC is 2.37 g/L. Determine the molar mass (molecular weight) of the compound. Give the molecular formula for the compound. Write the balanced chemical equation for the combustion reaction.
(d) The unknown compound is called methyl methanoate. What type of organic compound is methyl methanoate? Draw the molecule.
(e) Ethanoic acid is a structural isomer for the compound. What type of organic compound is ethanoic acid? Draw the molecule.

Answers:

(1) (a) (i) shift right (ii) shift left (iii) shift right (iv) no shift (b) At a lower temperature, the equilibrium would shift left (since the reaction is endothermic), decreasing the ratio of products to reactions, therefore K would be less than 1.4
(c) K = 14 (d) K = 0.27

(2) (a) (i) shift right (ii) shift left (iii) shift left (iv) shift right (b) Pressure = 0.747 atm
(c) K_p = 0.0898 atm (d) $K_c = 2.40 \times 10^{-3}$ M

(3) (a) $PbCrO_4\ (s) \rightleftharpoons Pb^{2+}\ (aq) + CrO_4^{2-}\ (aq)$ (b) $K_{sp} = [Pb^{2+}][CrO_4^{2-}]$ (c) $[CrO_4^{2-}] = 1.4 \times 10^{-8}$ M
(d) 4.5×10^{-7} g, $[CrO_4^{2-}] = 1.4 \times 10^{-8}$ M (concentration of ions in a saturated solution is independent of volume)
(d) $Q = 1.8 \times 10^{-6}$, Since Q>K, a ppt will form $[Pb^{2+}] = 0.0020$ M and $[CrO_4^{2-}] = 1.0 \times 10^{-13}$ M

(4) (a) $K_a = \dfrac{[H_3O^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}$ (b) pH = 2.936 (c) $HC_3H_5O_2 + OH^- \rightarrow C_3H_5O_2^- + H_2O$, volume NaOH = 100 mL
(d) (i) pH = 4.396 (ii) pH = 8.786 (iii) pH = 12.05 (e) (i) pH = 4.631
(ii) $HC_3H_5O_2 + OH^- \rightarrow C_3H_5O_2^- + H_2O$ (iii) $C_3H_5O_2^- + H_3O^+ \rightarrow HC_3H_5O_2 + H_2O$

(5) (a) Acidic: $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ (b) Basic $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ (c) Neutral (neither ion will hydrolyze)

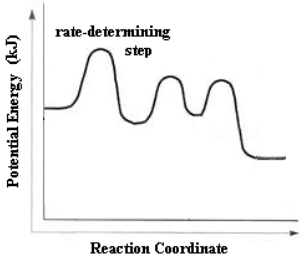
(6) (a) $2Ti^{3+} + H_2O + HOBr \rightarrow 2TiO^{2+} + 3H^+ + Br^-$ (b) Ti oxidized (+3 to +4), Br is reduced (+1 to –1)
(c) oxidizing agent: HOBr reducing agent: Ti^{3+}

(7) (a) cathode: $Ag^+ + e^- \rightarrow Ag$ (b) anode: $Fe \rightarrow Fe^{2+} + 2e^-$ (c) $2Ag^+ + Fe \rightarrow 2Ag + Fe^{2+}$ (d) 1.24 V
(e) $\xrightarrow{e-}$ $\xleftarrow{NO_3^-}$ $\xrightarrow{K^+}$ (f) Fe (anode) loses mass and Ag (cathode) gains mass
(g) $Fe\ (s) \mid Fe^{2+}\ (aq) \parallel Ag^+\ (aq) \mid Ag\ (s)$ (h) ΔG^o = –239 kJ (i) $K = 7.84 \times 10^{41}$
(j) (i) $[Ag^+] = 0.60$ M (ii) Q = 3.3 (iii) $E_{cell} < E^o_{cell}$ (k) (i) Q = 0.40 (iii) $E_{cell} > E^o_{cell}$

(8) (a) ΔH^o = –602 kJ/mol (b) ΔS^o_{MgO} = 27 J/mol K (c) ΔG^o = –570 kJ/mol, Since $\Delta G^o < 0$, the reaction is spontaneous. $\Delta H^o < 0$ which favours spontaneity, but $\Delta S^o < 0$ which does not favour spontaneity, therefore enthalpy is more responsible for the overall spontaneity of the reaction than entropy

(9) (a) 132 kJ (b) (i) –246.5 kJ/mol (ii) Since $\Delta G^o < 0$, the reaction is spontaneous. $\Delta H^o < 0$ which favours spontaneity, but $\Delta S^o < 0$ which does not favour spontaneity, therefore enthalpy is more responsible for the spontaneity of the reaction than entropy.
(iv) For T>1218 K, $\Delta G > 0$ (non-spontaneous) (iii) $K = 1.642 \times 10^{43}$ (c) 171 kJ/mol

(10) (a) F_2 = first order, ClO_2 = first order (b) k = 2.4 L mol^{-1} s^{-1} (c) $k = 2.4\ L\ mol^{-1}\ s^{-1}[F_2][ClO_2]$
(d) rate = 0.019 mol L^{-1} s^{-1} (e) 0.0012 mol F_2 L^{-1} s^{-1} (f) (i) Overall: $2ClO_2 + F_2 \rightarrow 2ClO_2F$
(ii) Step 1: The coefficients in the rate determining step equal the orders of each reactant in the rate law. In step 1 the coefficients for F_2 and ClO_2 are both one and in the rate law the orders for F_2 and ClO_2 are both one.
(iii)

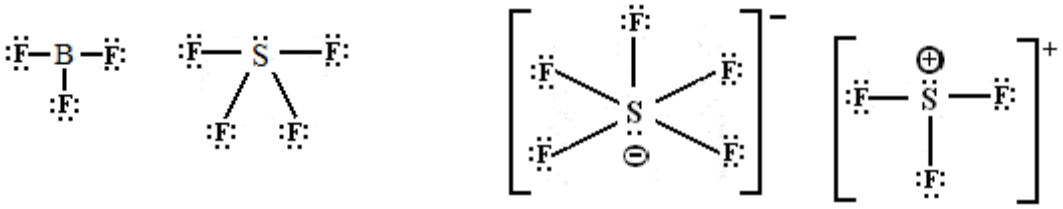


- the y-axis must be labelled with potential energy (kJ) and the x-axis must be labelled with reaction coordinate/progress
- the first step must have the highest activation energy and be labelled as the rate-determining step
- the final potential energy must be lower than the initial potential energy

(11) (a) $^{131}_{53}I \rightarrow {}^{0}_{-1}e + {}^{131}_{54}Xe$ (b) (i) First order (all nuclear reactions are first order) (ii) k = 0.0864 $days^{-1}$
(c) 22.0 days (d) 7.49%

(12) (a) (i) $\underset{1s}{\uparrow\downarrow}\ \underset{2s}{\uparrow\downarrow}\ \underset{2p}{\uparrow\downarrow\ \uparrow\ \uparrow}$ (ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$
(iii) O is paramagnetic (has unpaired electrons), Zn is diamagnetic (has no unpaired electrons). O would be attracted to a magnetic field. (b) (i) 9.57×10^{-19} J, 1.44×10^{15} Hz, 208 nm (ii) The fourth ionization (IE_4) since this would required the removal of core electrons (iii) Element X = boron, Element Y = sodium (iv) Element X/boron

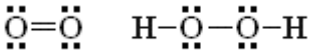
(13) (a) BF_3 SF_4 SF_5^- SF_3^+



(b) (i) 120º (ii) polar, the lone pair gives the molecule a dipole moment (iii) square pyramidal (iv) sp^3

(14) (a) Carbon has valence electrons in the n = 2 energy level. Fluorine has valence electrons in the n = 2 energy level and bromine has valence electrons in the n = 4 energy level.
Since bromine is a larger atom than fluorine, the bond length for the carbon to bromine bond longer than the bond length for the carbon to fluorine bond. Therefore, the bond length of the C-Br bond in CBr_4 expected to be longer than 134 picometers. Since carbon and fluorine have valence electrons in the same energy level, the orbital overlap between carbon and fluorine will be greater than between carbon and bromine. As a result, the bond between carbon and fluorine will be higher in energy that the bond between carbon and bromine. Therefore, the bond energy of the C-Br bond in CBr_4 is expected to be lower than 135 kJ/mol.
(b)

O_2 H_2O_2



The oxygen–oxygen bond in O_2 would be higher in energy than the oxygen-oxygen bond in H_2O_2 because O_2 has a double oxygen-oxygen bond and H_2O_2 has a single oxygen-oxygen.

(15) (a) diamond = network covalent
- hard, high density, high melting point

copper = metallic
- ductile and malleable, conducts heat and electricity, high melting point

sucrose = molecular
- soft, low melting point

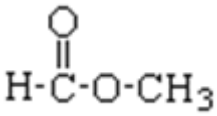
calcium chloride = ionic
- high melting point, brittle, soluble in polar solvents, will conduct electricity when molten/dissolved in water

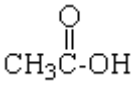
(b) CsCl<NaF<BaO
In the compound barium oxide, the ions each have a charge of two compared to the compounds sodium fluoride and cesium chloride in which the ions each have a charge of one. The higher the charge on the ion, the stronger the force of electrostatic attraction between the ions and the larger the lattice energy of the compound. Since barium oxide has the highest lattice energy, it has the highest melting point. In comparing sodium fluoride and cesium chloride, the relative size of ions must be considered. The smaller the ion, the stronger the force of electrostatic attraction and the larger the lattice energy. Since the sodium and fluoride ions are smaller than the cesium and chloride ions, sodium fluoride has a higher lattice energy than cesium chloride. As a result, the melting point of sodium fluoride is higher than the melting point of cesium chloride.
(c) (i) The alloy of gold and nickel is an interstitial alloy (since the atoms differ significantly in size) and is therefore hard and strong.
(ii) The alloy of nickel and chromium is a substitutional alloy (since the atoms are of comparable size) and is therefore ductile and malleable. The density of nichrome would be between 7.19 g/cm^3 and 8.91 g/cm^3.

(16) (a) methanamide: London dispersion forces, dipole interactions, hydrogen bonds
ethanal: London dispersion forces, dipole interactions
(b) methanamide: 210 ºC ethanal: 20.2 ºC (c) methanamide: 0.08 mmHg ethanal: 600 mmHg
(d) Distillation (separates the components of a solution based on their differing boiling points)

(17) (a) 7.42×10^{-3} mol H_2 (b) 0.180 g Mg

(18) (a) 0.0336 g H, 0.200 g C, and 0.266 g O (b) empirical formula = CH_2O
(c) molecular weight = 59.9 g/mol, molecular formula = $C_2H_4O_2$ $C_2H_4O_2 + 2O_2 \rightarrow 2CO_2 + 2H_2O$
(d) ester (e) carboxylic acid





AP Chemistry Multiple Choice Questions Semester 2

Questions 1 to 4 refer to the following types of energy.
(a) Activation energy
(b) Free energy
(c) Ionization energy
(d) Lattice energy

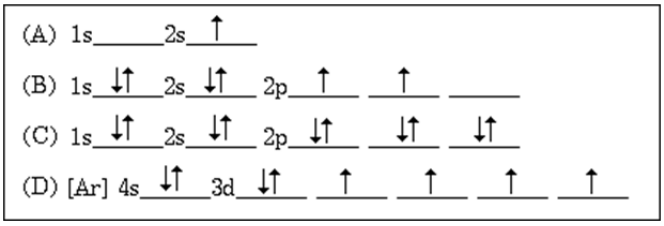
1. The energy required to convert an atom to a positive ion.

2. The energy change that occurs in the conversion of a gaseous ion to an ionic solid.

3. The energy in a chemical or physical change that is available to do useful work.

4. The energy required to form the transition state in a chemical reaction.

Question 5 to 8 refer to atoms for which the occupied atomic orbitals shown below.



5. Represents an atom that is chemically inert.

6. Represents an atom in an excited state.

7. Represents an atom that has four valence electrons.

8. Represents an atom of a transition metal.

Questions 9 to 12 refer to the following descriptions of bonding in different types of solids.

(a) Lattice of positive and negative ions held together by electrostatic forces.
(b) Malleable solid with delocalized electrons throughout.
(c) Molecules held together with strong covalent bonds.
(d) Molecules held together with weak intermolecular forces.

9. Cesium chloride, CsCl (s)

10. Gold, Au (s)

11. Silicon carbide, SiC (s)

12. Methane, CH_4 (s)

13. How many protons, electrons, and neutrons are in an $^{58}_{28}Ni^{2+}$ ion?

	Protons	Electrons	Neutrons
(a)	28	28	28
(b)	28	26	30
(c)	30	26	30
(d)	28	30	58

14. The melting point of MgO is higher than that of NaBr. Explanations for this observation include which of the following?
I. Mg^{2+} is more positively charged than Na^+
II. O^{2-} is more negatively charged than Br^-
III. The O^{2-} ion is smaller than the Br^- ion

(a) III only
(b) I and II only
(c) II and III only
(d) I, II, and III

15. Hydrogen gas is collected over water at 24°C. The total pressure is 755 mm Hg. At 24°C, the vapor pressure of water is 22 mm Hg. What is the partial pressure of the hydrogen gas?
(a) 22 mm Hg
(b) 733 mm Hg
(c) 755 mm Hg
(d) 777 mm Hg

16. Potassium chlorate decomposes into potassium chloride and oxygen according to the following balanced chemical equation: $2KClO_3 \rightarrow 2KCl + 3O_2$. If 12.3 g of potassium chlorate are completely reacted, approximately what mass of oxygen would be produced?
(a) 4.8 g
(b) 2.1g
(c) 9.6 g
(d) 6.4 g

17. When the equation below is balanced and all coefficients are reduced to the lowest whole number terms, which of the following gives the coefficient for Zn?
$\ldots Zn + \ldots NO_3^- + \ldots H^+ \rightarrow \ldots Zn^{2+} + \ldots NH_4^+ + \ldots H_2O$

(a) 2 (b) 4 (c) 6 (d) 10

18. Types of hybridization exhibited by the carbon atoms in propene, $CH_3CH{=}CH_2$, include which of the following?
I. sp II. sp^2 III. sp^3

(a) I only
(b) III only
(c) II and III only
(d) I and II only

Experiment	Initial [NO] (mol L^{-1})	Initial [O_2] (mol L^{-1})	Initial Rate of Formation of NO_2 (mol L^{-1} s^{-1})
1	0.10	0.10	2.5×10^{-4}
2	0.20	0.10	5.0×10^{-4}
3	0.20	0.40	8.0×10^{-3}

19. The initial-rate data in the table above were obtained for the reaction represented below. What is the experimental rate law for the reaction?
(a) rate = k[NO] $[O_2]$
(b) rate = k[NO] $[O_2]^2$
(c) rate = k$[NO]^2$ $[O_2]$
(d) rate = k$[NO]^2$ $[O_2]^2$

20. Of the following molecules, which has the largest dipole moment?
(a) SiH_4
(b) CO_2
(c) HF
(d) F_2

21. Which of the following does **NOT** behave as an electrolyte in water?
(a) CH_3OH
(b)LiBr
(c) HI
(d) NaOH

22. Under which of the following sets of conditions could the most O_2 (g) be dissolved in H_2O (l)?

	Pressure of O_2(g) above H_2O (l) (atm)	Temperature of H_2O (l) °(C)
(a)	5.0	80
(b)	5.0	20
(c)	1.0	80
(d)	0.5	20

23. When solid ammonium chloride, NH_4Cl (s) is added to water at 25 °C, it dissolves and the temperature of the solution decreases. Which of the following is true for the values of ΔH and ΔS for the dissolving process?

	ΔH	ΔS
(a)	Postive	Positive
(b)	Positive	Negative
(c)	Negative	Positive
(d)	Negative	Negative

For questions 24 to 27 consider atoms of the following elements:
(a) Potassium (K)
(b) Magnesium (Mg)
(c) Nitrogen (N)
(d) Neon (Ne)

24. Has the largest atomic radius.

25. Has the highest first ionization energy.

26. Has the highest electronegativity.

27. Has the largest increase in ionization energy between the second ionization and the third ionization.

28. $4NH_3$ (g) + $3O_2$ (g) → $2N_2$ (g) + $6H_2O$ (g)
If the standard heat of formation of ammonia, NH_3 (g) is –46 kJ/mol and of gaseous water, H_2O (g) is –242 kJ/mol, what is the enthalpy, ΔH^o of the above reaction?
(a) –288 kJ/mol (c) –1268 kJ/mol
(b) –576 kJ/mol (d) –1636 kJ/mol

29. A 0.10 M solution of which of the following salts is the most **basic**?
(a) CaI_2 (c) K_2CO_3
(b) $Al(NO_3)_3$ (d) NH_4Cl

30. A + 3B → C + 2D
For the reaction represented above, the initial rate of disappearance of A is 0.028 mol L^{-1} s^{-1}. What is the initial rate of formation of D?
(a) 0.014 mol L^{-1} s^{-1} (c) 0.028 mol L^{-1} s^{-1}
(b) 0.084 mol L^{-1} s^{-1} (d) 0.056 mol L^{-1} s^{-1}

31. The salt lead (II) chloride, $PbCl_2$has Ksp = $1.6x10^{-5}$. Which of the following gives an expression for the molar solubility?

(a) $\sqrt{1.6x10^{-5}}$ (c) $\sqrt{4.0x10^{-6}}$
(b) $\sqrt[3]{8.0x10^{-6}}$ (d) $\sqrt[3]{4.0x10^{-6}}$

32. The value of K_a for a weak monoproticacid, HA is $2.5x10^{-6}$. Which of the following gives the approximate pH for a 0.40 M solution of HA.
(a) 2.0 (b) 3.0 (c) 4.0 (d) 6.0

33. In 500 mL of a solution of $MgCl_2$, $[Cl^-]$ = 0.40 M. What is $[Mg^{2+}]$ in the solution?
(a) 0.20 M (c) 0.60 M
(b) 0.40 M (d) 0.80 M

Questions 34 and 35 refer to the following reaction mechanism:

Step 1: $Ce^{4+} + Mn^{2+} \rightarrow Ce^{3+} + Mn^{3+}$
Step 2: $Ce^{4+} + Mn^{3+} \rightarrow Ce^{3+} + Mn^{4+}$
Step 3: $Mn^{4+} + Tl^{+} \rightarrow Tl^{3+} + Mn^{2+}$

34. The proposed steps for a catalyzed reaction between Ce^{4+} and Tl^+ are represented above. The *products* of the overall reaction are
(a) Ce^{3+} and Mn^{3+} (c) Ce^{3+} and Mn^{4+}
(b) Ce^{3+} and Tl^{3+} (d) Tl^{3+} and Mn^{2+}

35. Which of the substances acts as a catalyst in this reaction?
(a) Mn^{4+} (b) Ce^{3+} (c) Tl^{3+} (d) Mn^{2+}

36. Ethanol, CH_3CH_2OH boils at 78 ºC and dimethyl ether, CH_3OCH_3 boils at –24 ºC, although both compounds have the same composition. This difference in boiling points may be attributed to a difference in which of the following?
(a) molecular mass (c) hydrogen bonding
(b) density (d) heat of combustion

37. For which of the following processes would ΔS^o have a negative value?

I. $2Fe_2O_3$ (s) → 4 Fe (s) + $3O_2$ (g)
II. Mg^{2+} (aq) + $2OH^-$ (aq) → $Mg(OH)_2$ (s)
III. H_2 (g) + C_2H_4 (g) → C_2H_6 (g)

(a) I only (c) I and III only
(b) I and II only (d) II and III only

38. Which of the following gives the hybridization of the central atom in the molecule $SbCl_5$?
(a) sp^2 (b) sp^3 (c) dsp^3 (d) d^2sp^3

39. H_2 (g) + I_2 (s) + 26 kJ/mol → 2HI (g)
Which of the following gives the amount of heat required to produce 10 moles of HI (g)?
(a) 5.2 kJ (c) 130 kJ
(b) 260 kJ (d) 520 kJ

40. Molecules that have planar configurations include which of the following?
I. BCl_3 II. $CHCl_3$ III. NCl_3

(a) I only (c) II and III only
(b) I and III only (d) I, II, and III

N_2 (g) + 3 H_2 (g) → 2 NH_3 (g)
41. The above reaction is thermodynamically favorable at 298 K, but becomes unfavorable at higher temperatures. Which of the following is true at 298 K?

(a) ΔG, ΔH, and ΔS are all positive.
(b) ΔG, ΔH, and ΔS are all negative.
(c) ΔG and ΔH are negative, but ΔS is positive.
(d) ΔG and ΔH are positive, but ΔS is negative.

42. I_2 (g) + 3 Cl_2 (g) → 2 ICl_3 (g)
According to the data in the table below, what is the value of ΔH^o for the reaction represented above?

Bond	Average Bond Energy (kJ mol $^{-1}$)
I–I	149
Cl–Cl	239
I–Cl	208

(a) –860 kJ/mol
(b) –382 kJ/mol
(c) +180 kJ/mol
(d) +450 kJ/mol

For question 43 to 46 consider the molecules of the following compounds.

(a) H_2S (b) NH_3 (c) BH_3 (d) CO_2

43. Has two unshared pairs of electrons on the central atom.

44. Has the largest bond angle.

45. Has trigonal pyramidal molecular geometry.

46. Has a central atom with less than an octet of electrons.

47. At 25 ºC, a sample of NH_3 effuses at the rate of 0.050 mole per minute. Under the same conditions, which of the following gases effuses at approximately one–half that rate?
(a) O_2 (b) CH_4 (c) CO_2 (d) Cl_2

48. Which of the following molecule is non-polar?
(a) CBr_4
(b) SO_2
(c) NF_3
(d) Cl_2O

49. Cu (s) + $2Ag^+$ (aq) $\rightleftharpoons$ Cu^{2+} (aq) + 2Ag (s)
If the equilibrium constant for the reaction above is $3.7x10^{15}$. Which of the following correctly describes the standard voltage, E˚, and the standard free energy change, Δ G˚, for this reaction?
(a) E˚ is positive and ΔG˚ is negative.
(b) E˚ is negative and ΔG˚ is positive.
(c) E˚ and ΔG˚ are both positive.
(d) E˚ and ΔG˚ are both negative.

50. Pi (π) bonding occurs in each of the following substances EXCEPT
(a) CO_2
(b) C_2H_4
(c) C_6H_6
(d) CH_4

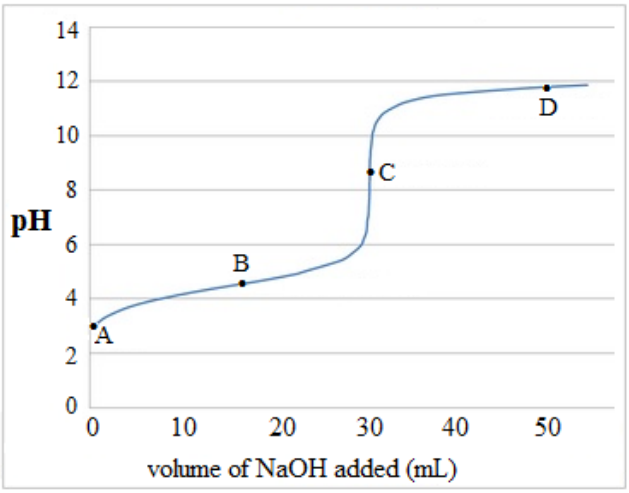
51. Consider the following reduction reactions:
Zn^{2+} (aq) + $2e^-$ → Zn (s) Eº = –0.76 V
Al^{3+} (aq) + $3e^-$ → Al (s) Eº = –1.66 V

What is the standard potential for the reaction represented below?

$3Zn^{2+}$ (aq) +2Al (s) → 3Zn (s) + $2Al^{3+}$ (aq)

(a) 0.90 V
(b) 1.04 V
(c) 3.46 V
(d) 0.62 V

Consider the following titration curve of an unknown monoprotic acid to answer questions 52 to 54



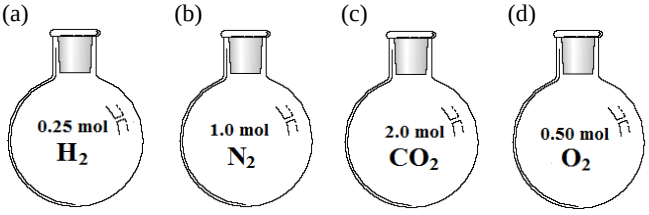
52. At which point is [H_3O^+] the highest?
(a) A (b) B (c) C (d) D

53. At which point is the number of moles of HA equal to the number of moles of A^-?
(a) A (b) B (c) C (d) D

54. Which of the following could be the identity of unknown acid
(a)Hydrocyanic acid, pK_a = 9.2
(b) Hydrofluoric acid, pK_a = 3.1
(c)Hypochlorous acid, pK_a = 7.5
(d)Hydrazoic acid, pK_a = 4.6

For Questions 55 and 56, consider samples of the following gases in 1.0 L flasks at 25 ºC.

(a) (b) (c) (d)



55. Which of the flasks has particles with the highest speed?

56. Which of the gases would be under the most pressure?

57. For which of the following equilibria would increasing the volume cause a shift towards the products?
(a) CO (g) + H_2O (g) $\rightleftharpoons$ CO_2 (g) + H_2 (g)
(b) PCl_5 (g) $\rightleftharpoons$ PCl_3 (g) + Cl_2 (g)
(c) O_2 (g) + $4NO_2$ (g) $\rightleftharpoons$ $2N_2O_5$ (g)
(d) H_2 (g) + F_2 (g) $\rightleftharpoons$ 2HF (g)

58. Using the information given below:

$\frac{1}{2}N_2\,(g) + O_2\,(g) \rightarrow NO_2\,(g) \quad \Delta H° = 33$ kJ/mol

$N_2\,(g) + 2O_2\,(g) \rightarrow N_2O_4\,(g) \Delta H° = 9$ kJ/mol

Determine the enthalpy change of the following reaction:
$N_2O_4\,(g) \rightarrow 2NO_2\,(g)$.

(a) 42 kJ/mol
(b) 75 kJ/mol
(c) 57 kJ/mol
(d) –24 kJ/mol

59. Consider the following equilibrium:
$SO_3\,(g) \rightleftharpoons SO_2\,(g) + \frac{1}{2}O_2\,(g)$ K = 0.060
Which of the following gives an expression for the equilibrium constant for reaction shown: $2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$

(a) $K = \frac{1}{0.12}$
(b) $K = \frac{1}{(0.060)^2}$
(c) $K = (0.060)^2$
(d) $K = \sqrt{0.060}$

60. Which of the following would be the product if Tl-207 releases a beta particle?
(a) $^{207}_{82}Pb$
(b) $^{208}_{82}Pb$
(c) $^{203}_{79}Au$
(d) $^{207}_{81}Hg$

Answer Key: AP Chemistry Multiple Choice Questions

(1) c	(11) c	(21) a	(31) d	(41) b	(51) a
(2) d	(12) d	(22) b	(32) b	(42) b	(52) a
(3) b	(13) b	(23) a	(33) a	(43) a	(53) b
(4) a	(14) d	(24) a	(34) b	(44) d	(54) d
(5) c	(15) b	(25) d	(35) d	(45) b	(55) a
(6) a	(16) a	(26) c	(36) c	(46) c	(56) c
(7) b	(17) b	(27) b	(37) d	(47) d	(57) b
(8) d	(18) c	(28) c	(38) c	(48) a	(58) c
(9) a	(19) b	(29) c	(39) c	(49) a	(59) b
(10) b	(20) c	(30) d	(40) a	(50) d	(60) a