Exam 2

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

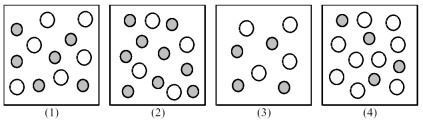
1. What is the best strategy to avoid contact with corrosive chemicals?
   1. Wear chemical splash goggles.
   2. Wear appropriate gloves.
   3. Wear an apron.
   4. Always work in a chemical hood.
2. all of the above The reaction that occurs in a Breathalyzer, a device used to determine the alcohol level in a person’s bloodstream, is given below. If the rate of appearance of chromium(III) sulfate is 1.24 mol/min at a particular moment, what is the rate of disappearance of ethanol, C2H5OH, at that moment?

2 K2Cr2O7 (aq) + 8 H2SO4 (aq) + 3 C2H5OH (aq) → 2 Cr2(SO4)2 (aq) + 2 K2SO4 (aq) + 11 H2O (l)

* 1. 0.413 mol/min
  2. 0.826 mol/min
  3. 1.86 mol/min
  4. 3.72 mol/min
  5. none of the above

1. For a reaction that follows the general rate law, rate = k[A][B]2, what will happen to the rate of reaction if the concentration of B is increased by a factor of 2.00? The rate will
   1. decrease by a factor of 1/4.00.
   2. decrease by a factor of 1/2.00.
   3. increase by a factor of 2.00.
   4. increase by a factor of 4.00.
   5. remain constant.
2. A zeroth order reaction is one whose
   1. rate is zero.
   2. rate is independent of reactant concentration.
   3. rate can be found where [A]t = -kt + ln[A]0.
   4. rate is dependent on none of the above
   5. rate is dependent on all of the above
3. What factors affect the rate of a chemical reaction?
   1. collision frequency
   2. fraction of collisions with sufficient energy
   3. orientation of molecules
   4. all of the above
   5. none of the above

The following pictures represent solutions of calcium carbonate, which may also contain ions other than Ca2+ and CO32-, which are not shown. Gray spheres represent Ca2+ ions and unshaded spheres represent CO32- ions.



1. If solution (1) is a saturated solution of calcium carbonate, which of the solutions (1) – (4) represents the solution after a small amount of NaOH is added and equilibrium is restored?
   1. (1)
   2. (2)
   3. (3)
   4. (4)
   5. not enough information
2. If solution (1) is a saturated solution of calcium carbonate, which of the solutions (1) – (4) represents the solution after a small amount of Ca(NO3)2 is added and equilibrium is restored?
   1. (1)
   2. (2)
   3. (3)
   4. (4)
   5. not enough information
3. Which of the following states is not true?
   1. The reverse of a spontaneous reaction is always nonspontaneous.
   2. A spontaneous process always moves toward equilibrium.
   3. A nonspontaneous process cannot be caused to occur.
   4. A highly spontaneous process need not occur rapidly.
   5. all of the above
4. Entropy is a measure of
   1. free energy.
   2. the heat of a reaction.
   3. molecular randomness.
   4. the rate of reaction.
   5. temperature.

1. Why is the sign of ∆G rather than the sign of ∆Stotal generally used to determine the spontaneity of a chemical reaction?
   1. ∆G can be used for processes that occur under any condition.
   2. ∆G involves thermodynamic functions of the system only.
   3. Free energy is easier to understand than entropy.
   4. Entropy is based on probability and is therefore less reliable.
   5. none of the above

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. What is the value of the equilibrium constant, Knet, for dissolving silver bromide in a solution containing the thiosulfate ion, S2O32-? When solid silver bromide is added to aqueous sodium thiosulfate the complex ion dithiosulfatoargentate(I), [Ag(S2O3)2]3-, is formed. Does silver bromide dissolve readily on adding aqueous sodium thiosulfate to the solid? (Ksp for AgBr is 5.0 × 10-13 and Kf for [Ag(S2O3)2]3- is 2.9 × 1013 (5 points).

AgBr (s) Ag+ (aq) + Br- (aq) Ksp = 5.0 × 10-13

Ag+ (aq) + 2 S2O32- (aq) [Ag(S2O3)2]3- (aq) Kf = 2.9 × 1013

AgBr (s) + 2 S2O32- (aq) [Ag(S2O3)2]3- (aq) + Br- (aq) Knet = Ksp × Kf = 15

Silver bromide is predicted to dissolve readily in aqueous sodium thiosulfate because the value of Knet is greater than 1, indicating a product-favored reaction at equilibrium.

1. A common laboratory method for preparing a precipitate is to mix solutions containing the component ions Does a precipitate form when 0.100 L of 0.15 M Ca(NO3)2 is mixed with 0.200 L of 0.060 M NaF? The Ksp of the precipitate is 3.2 × 10-11. Show work to justify your answer (6 points).

CaF2 (s) Ca2+ (aq) + 2 F­- (aq) Ksp = [Ca2+][F-]2

Qsp > Ksp, therefore a precipitate will form.

1. Are the following processes spontaneous or nonspontaneous (4 points)?
   1. A bike going up a hill. \_\_\_\_nonspontaneous\_\_\_\_
   2. A meteor falling to Earth. \_\_\_\_spontaneous\_\_\_\_\_\_\_
   3. Obtaining oxygen gas from liquid water. \_\_\_\_nonspontaneous\_\_\_\_\_\_\_\_
   4. A whiteboard marker rolling down a ramp. \_\_\_\_spontaneous\_\_\_\_\_\_\_\_\_\_
2. The aquation of tris(1,10-phenanthroline)iron(II) in acid solution takes place according to the equation: Fe(phen)32+ (aq) + 3 H3O+ (aq) + 3 H2O (l) → Fe(H2O)62+ (aq) + 3 phenH+ (aq)

If the activation energy, Ea, is 126 kJ/mol and the rate constant at 30°C is 9.8 × 10-3 min-1, what is the rate constant at 50 °C (6 points)?

1. Calcium hydroxide (slaked lime) is a major component of mortar, plaster, and cement, and solutions of Ca(OH)2 are used in industry as a strong, inexpensive base (11 points).
   1. Calculate the molar solubility of Ca(OH)2 in water is Ksp = 6.5 × 10-6.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Ca(OH)2 (s) | Ca2+ (aq) + | 2 OH- (aq) |
| I | n/a | 0 M | ~0M |
| C | n/a | +S | + 2S |
| E | n/a | S = 1.2 × 10-2 M | 2S =  (2)(1.2 × 10-2 M) =  2.4 × 10-2M |

Check

* 1. What is its solubility in 0.10 M Ca(NO3)2?

|  |  |  |  |
| --- | --- | --- | --- |
|  | Ca(OH)2 (s) | Ca2+ (aq) + | 2 OH- (aq) |
| I | n/a | 0.10 M | ~0M |
| C | n/a | +S | + 2S |
| E | n/a | 0.10 M + S =  0.10 M + 4.0 × 10-3 M ≈ 0.10 M | 2S =  2(4.0 × 10-3 M) =  8.0 × 10-3 M |

Approximation check

Check

1. Answer the following questions about the following mechanism (8 points).

Step 1: A + B C (fast)

Step 2: B + C 🡪 D (slow)

1. What is the rate law?

B + C 🡪 D (slow) rate = k2[B][C]

+ A + B C (fast) rate = k1[A][B] = k-1[C]

A + 2 B 🡪 D [C] = [A][B] substitute in to first equation so

rate = [A][B]2

Based on the balanced chemical equation the rate = k[A][B]2.

So, both rate laws match.

1. What is the overall order of the reaction? \_\_\_3\_\_
2. What is the molecularity of step 2? \_\_\_\_bimolecular\_\_\_\_\_\_
3. The following statements relate to the reaction for the formation of HI:

H2 (g) + I2 (g) →2 HI (g) rate = k[H2][I2]

Determine which of the following statements are true. If a statement is false, indicate why it is incorrect (10 points).

* 1. The reaction must occur in a single step.

False. The reaction may occur in a single step, but this does not have to be true.

* 1. This is a second-order reaction overall.

True

* 1. Raising the temperature will cause the value of k to decrease.

False. Raising the temperature increases the value of k.

* 1. Raising the temperature lowers the activation energy for this reaction.

False. Temperature has no effect on the value of Ea.

* 1. If the concentration of both reactants are doubled, the rate will double.

False. If the concentrations of both reactants are doubled, the rate will increase by a factor of four.

* 1. Adding a catalyst in the reaction will cause the initial rate to increase.

True

1. Assuming the activation energies are equal, which of the following reactions will proceed at a higher rate at 50 °C? Explain (4 points).

NH3 (g) + HCl (g) → NH4Cl (s)

N(CH3)3 (g) + HCl (g) → (CH3)3NHCl (s)

At the same temperature, both reaction mixtures have the same average kinetic energy, but the reactant molecules do not have the same average velocity. The trimethylamine molecule has a greater mass than the ammonia molecule, so trimethylamine molecules will collide less often with HCl. Moreover, the bulky groups bonded to nitrogen in trimethylamine mean that collisions with HCl having the correct orientation will occur less frequently. Therefore, the rate of the reaction between NH3 and HCl will be higher.

1. Radioactive decay is a first-order process. Radioactive radon-222 gas (222Rn) occurs naturally as a product of uranium decay. The half-life of radon-222 is 3.8 days. Suppose a flask originally contained 4.0 × 1013 atoms of radon-222 (8 points).
   1. What is the rate constant k?
   2. How many atoms of radon-222 will remain after one month (30 days)?
2. Is the dissolving of sodium chloride in water at 298 K a spontaneous under standard conditions given that ∆S°system is 43.4 J/K and ∆S°surroundings is -12.9 J/K (4 points)?

∆S°universe = ∆S°system + ∆S°surroundings = 43.4 J/K + (-12.9 J/K) =30.5 J/K

The entropy of the universe increases so this is a spontaneous process.

1. Calculate the change in entropy in J/K that occurs in the system when 4.10 moles of diethyl ether (C4H6O) condenses from a gas to a liquid at its normal boiling point (34.6 °C). ∆Hvap = 26.5 kJ/mol (6 points).
2. Consider the balanced equation (8 points):

6 OH- (aq) + 3 I2 (s) 🡪 IO3- (aq) + 3 H2O (l) + 5 I- (aq)

1. Calculate ∆G° for the reaction at 25 °C.

|  |  |
| --- | --- |
| Substance | ∆G° f (kJ/mol) |
| I2 (s) | 0 |
| IO3- (aq) | -128.0 |
| I- (aq) | -51.57 |
| H2O (l) | -237.1 |
| OH- (aq) | -157.3 |

ΔG°f = [(1 mol)(ΔG° IO3- (aq)) + (3 mol)(ΔG° H2O (l)) + (5 mol)(ΔG° I- (aq))] – [(6 mol)(ΔG° OH- (aq) + (3 mol)(ΔG° I2 (s))]

ΔG°f = [(1 mol)(-128.0 kJ/mol) + (3 mol)(-237.1 kJ/mol) + (5 mol)(-51.57 kJ/mol)] – [(6 mol)(-157.3 kJ/mol) + (3 mol)(0 kJ/mol)]

ΔG°f = -128.0 kJ + -711.3 kJ + -257.85 kJ – (-943.8 kJ)

ΔG°f = -153.4 kJ

1. Is the reaction spontaneous or nonspontaneous under standard-state conditions? Spontaneous