Exam 1

# Part 1: Multiple Choice (2 points each)

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

1. Which of the following equilibria will shift toward formation of more products if an equilibrium mixture is compressed into half its volume?
   1. 2 N2O 2 N2 (g) + O2 (g)
   2. 2 CO (g) + O2 (g) 2 CO2 (g)
   3. N2 (g) + O2 (g) 2 NO (g)
   4. 2 NO (g) + O2 (g) 2 NO2 (g)
   5. b and d
2. A rate is equal to 0.0200 M/s. If [A] = 0.100 M and rate = k[A]0, what is the new rate if the concentration of [A] is increased to 0.200 M?
   1. 0.0200 M/s
   2. 0.0400 M/s
   3. 0.0600 M/s
   4. 0.0800 M/s
   5. 0.100 M/s
3. Identify the rate-determine step.
   1. The slowest step
   2. The faster step
   3. The fast step
   4. Always the last step
   5. Always the second step
4. What is the ∆n for the following equation in relating Kc to Kp?

4 NH3 (g) + 3 O2 (g) 2 N2 (g) + 6 H2O (g)

* 1. -5
  2. -3
  3. -2
  4. 0
  5. 1

1. The following reaction is exothermic. Which change will shift the equilibrium to the left?

2 SO2 (g) + O2 (g) 2 SO3 (g)

* 1. Increase the volume
  2. Adding He
  3. Decrease the volume
  4. all of the above
  5. none of the above

1. Carbon dioxide combines with rainwater to form
   1. Phosphoric acid
   2. Carbonic acid
   3. Nitric acid
   4. Sulfuric acid
   5. Nitrous acid
2. Which one of the following salts, when 1 mole is dissolved in water, produces the solution with a pH closest to 7.00?
   1. NH4ClO4
   2. Na2O
   3. NaHSO4
   4. NaF
   5. NaOH
3. An Arrhenius acid
   1. donates an electron pair.
   2. is a H+ donor.
   3. is a H+ acceptor.
   4. produces OH- in aqueous solution.
   5. produces H+ in aqueous solution.
4. What is the conjugate acid of the Brønsted-Lowry acid HPO42-?
5. H3PO4
6. H2PO4-
7. HPO42-
8. PO43-
9. none of the above
10. A student should attempt to use a fire extinguisher
    1. only if an instructor says it is okay.
    2. always, before sounding an alarm or alerting anyone else.
    3. only if the fire is small enough and the student can confidently use the available extinguisher.
    4. on all fires, no matter how small or large because the fire will certainly get larger and cause considerable damage.
    5. all 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.

|  |  |  |
| --- | --- | --- |
| [NO]i (M) | [O2]i (M) | Initial Rate (M-1 s-1) |
| 0.030 | 0.0055 | 8.55 × 10-3 |
| 0.030 | 0.0110 | 1.71 × 10-2 |
| 0.060 | 0.0055 | 3.42 × 10-2 |

1. Determine the rate law and the value of k for the following reaction using the data provided (15 points).

2 NO (g) + O2 (g) → 2 NO2 (g)

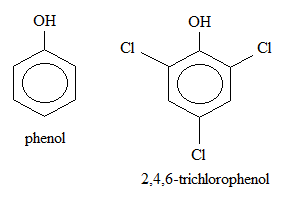
Rate = (1.7 × 103 1/M2 s)[O2] [NO]2

1. In the following mechanism for NO formation, oxygen atoms are produced by breaking O=O bonds at high temperature in a fast reversible reaction. If Δ[NO]/Δt = *k*[N2][O2]1/2, which step in the mechanism is the rate-determining step? Show how the rate law is determined (8 points).
2. O2 (g) 2 O (g)
3. O­ (g) + N2 (g) → NO (g) + N (g)
4. N (g) + O (g) → NO (g)

Overall: N2 (g) + O2 (g) → 2 NO (g)

The second step is the rate determining step.

1. The values of Ka for phenol and 2,4,6-trichlorophenol are 1.3 x 10-10 and 1.0 x 10-6, respectively. Which is the stronger acid? Account for the differences in acid strength using the structures below (5 points):



The larger the Ka value, the stronger the corresponding acid.

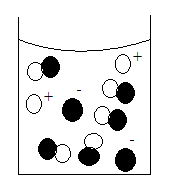
2,4,6-Trichlorophenol is the stronger acid because the chlorines have a greater electron-withdrawing power than the hydrogens they replaced in the unsubstituted phenol.

1. A new potential heart medicine, code-named X-281, is being tested by a pharmaceutical company, Pharma-pill. As a research technician at Pharma-pill, you are told that X-281 is a monprotic weak acid, but because of security concerns, the actual chemical formula must remain top secret. The company is interested in the drug’s Ka value because only the dissociated form of the chemical is active in preventing cholesterol buildup in arteries (14 points).
   1. To find the Ka of X-281, you prepare a 0.058 M test solution of X-281. The pOH of the solution is determined to be 11.15. What is the pH of the solution?
   2. What is the Ka of X-281?

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| HX (aq) | + | H2O (l) |  | H3O+ (aq) | + | X- (aq) |
| 0.058 M |  | ∞ |  | ~0 M |  | 0 M |
| -x |  | ∞ |  | +x |  | +x |
| 0.058 M –x =  0.058 M – 0.0014 M =  0.057 M |  | ∞ |  | x = 0.0014 M |  | x = 0.0014 M |

* 1. What is the Kb? Assume the solution is at 25 °C.

1. What is the Ka of the monoprotic acid indicated by the diagram below (4 points)?



1. The central idea of the collision model is that molecules must collide in order to react. Give two reasons why not all collisions of reactant molecules result in production formation (4 points).

Two reactions are: 1) the collision must involve enough energy to produce the reaction; i.e., the collision energy must equal or exceed the activation energy. 2) the relative orientation of the reactants must allow formation of any new bonds necessary to produce products.

1. Which solution has the higher pH? Explain (10 points).
   1. A 0.1 M solution of an acid with Ka = 1 × 10-4 or one with Ka = 4 × 10-5.

The acid with the smaller Ka (1 × 10-5) has the higher pH, because less dissociation yields fewer hydronium ions.

* 1. A 0.1 M solution of an acid with pKa = 3.0 or one with a pKa = 3.5.

The acid with the larger pKa (3.5) has the higher pH, because it has a smaller Ka and, thus lower [H3O+]

* 1. A 0.1 M solution or a 0.01 M solution of a weak acid.

Lower concentration (0.01 M) contains fewer hydronium ions.

* 1. A 0.1 M solution of a weak acid or a 0.1 M solution of a strong base.

A 0.1 M weak acid solution contains fewer hydronium ions.

1. For the equilibrium: C (s) + 2 H2 (g) CH4 (g) + heat

For each of the following changes to the system at equilibrium, predict the direction of the shift and explain why it occurs (8 points):

|  |  |  |
| --- | --- | --- |
| **Change** | **Shift** | **Reason** |
| The volume of the reaction vessel is doubled. | **left** | **Volume change causes P to drop. Shift left makes more moles of gas and therefore a higher pressure** |
| The temperature is increased. | **left** | **shifts left to use up heat** |
| The pressure of H2 (g) is increased. | **right** | **Shifts to the right to decrease the moles of H2. Reaction rate to right increases, to the left stays the same so there is a net shift to the right.** |
| Adding a catalyst | **no change** | **A catalyst does not affect the position of the equilibrium. (So then, just what does it do?)** |

1. A mixture of 0.0200 mol oxygen gas and 0.0200 mol dinitrogen monoxide is placed in a 1.00 L reaction vessel at 25 °C. When the reaction is at equilibrium 0.0200 mol nitrogen dioxide is present (14 points).

2 N2O (g) + 3 O2 (g) 4 NO2 (g)

1. What are the equilibrium concentrations of oxygen and dinitrogen monoxide gas?

2 N2O (g) + 3 O2 (g)  4 NO2 (g)

I 0.0200 M 0.020 M 0 M

C -2x -3x +4x

E 0.0200 M – 2x 0.0560 M – 3x 4x

F 0.0200 M – (2(0.00500 M)) = 0.0200 M – (3(0.00500 M)) = 0.0200 M

0.0100 M 0.0050 M

4x = 0.0200 M

x = 0.00500 M

1. Calculate Kc for the reaction at equilibrium.
2. How will Kc change if the reaction is reversed?

Kc` = 1/Kc = 1/1.3 × 104 M-1 = 7.8 × 10-5 M