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| **Name:** |  |
| **Your Score:** |  |
| **Maximum Score:** | **40** |

**AP CHEMISTRY**

**UNIT 08ABCDEFGHIJK TEST**

## Instructions

* **Write your name at the top of this page**
* **You are provided with an equations & constants sheet, and a periodic table**
* **In SECTION A you will find multiple-choice questions. Answer these by choosing the one letter that corresponds to the best answer**
* **In SECTION B you will find a number of free response questions. Write your answers in the spaces provided. The number of points for each part of each question is shown in parentheses**
* **Attempt ALL the questions**
* **Where appropriate show ALL working and pay attention to units and significant figures**
* **Present all your work as neatly as possible**

**SECTION A: Multiple-Choice (Select the best answer)**

1. Which description best defines the role of HCl in the reaction below? (8.1)

HCl(aq) + H2O(l) 🡺 H3O+(aq) + Cl-(aq)

(A) Arrhenius base

(B) Brønsted Lowry acid

(C) Brønsted Lowry base

(D) Conjugate acid

2. An acidic solution with a volume of 1.00 L has a certain pH. What volume of water must be added to the solution in order to raise the pH by one unit? (8.1)

(A) 0.1 L

(B) 0.3 L

(C) 1.0 L

(D) 9.0 L

3. A solution with a [OH-] = 1 x 10-2 at 298 K is (8.1)

(A) Neutral

(B) Basic

(C) Acidic

(D) One with a [H3O+] = 1 x 10-2

Questions 4 and 5

4. Given the information below, where acid strength increases from left to right, which of the following equilibria lie heavily to the product (right-hand) side? (8.3)

**Weakest Acid** NH3 < H2O < HCN < C2H5COOH < HCl **Strongest Acid**

(A) CN- + H2O ⇌ HCN + OH-

(B) C2H5COOH + Cl- ⇌ HCl + C2H5COO-

(C) HCl + CN- ⇌ HCN + Cl-

(D) HCN + C2H5COO- ⇌ C2H5COOH + CN-

5. Of the following, which of the following is the weakest base? (8.3)

(A) CN-

(B) C2H5COO-

(C) Cl-

(D) OH-

6. Sulfuric acid H2SO4, is a diprotic acid with the following Ka values;

Ka1 = very large

Ka2 = 1 x 10-2

What do these Ka values suggest about sulfuric acid? (8.3)

(A) That the amount of dissociated H2SO4 in solution is negligible

(B) That the amount of H+ in solution is negligible

(C) That the species with the largest concentration in solution will be SO42-

(D) That HSO4- is a weaker acid that H2SO4

7. At the equivalence point in a titration between a strong acid and a weak base, the pH is found to be which of the following, and for what reason? (8.5)

(A) pH = 7, since all neutralizations are neutral at the equivalence point

(B) pH < 7, since the pH of the acid and base average out to be less than 7

(C) pH < 7, since the cation of the salt hydrolyzes to yield H3O+

(D) pH < 7, since the anion of the salt hydrolyzes to yield OH-

Questions 8 and 9

In an experiment to determine the molarity of a strong acid, a known mass of a solid base

is dissolved in known volume of water, and this solution is used as the primary standard.

A specific volume of the standard solution is then titrated with the acid until a sharp end

point is reached.

8. Which of the following lists appropriate glassware for the procedure? (8.5)

(A) Erlenmeyer flask for making up the standard solution; glass pipet for transferring standard solution; buret for adding acid

(B) Volumetric flask for making up the standard solution; glass pipet for transferring standard solution; buret for adding acid

(C) Volumetric flask for making up the standard solution; funnel for transferring standard solution; pipet for adding acid

(D) Erlenmeyer flask for making up the standard solution; buret for transferring standard solution; beaker for adding acid

9. In the experiment the student “overshoots” the end–point, i.e., adds too much titrant. What are the consequences of this error? (8.5)

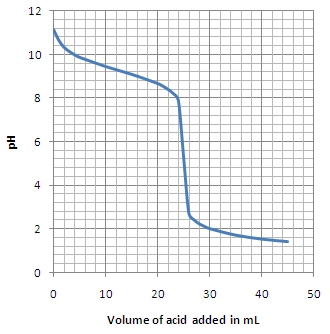
(A) Too much acid is added, and the calculated molarity of the acid is too large

(B) Too much acid is added, and the calculated molarity of the acid is too small

(C) Too little acid is added, and the calculated molarity of the acid is too large

(D) Too little acid is added, and the calculated molarity of the acid is too small

10. Consider the titration curve shown below that shows the variation of pH during the titration of a base with an acid. (8.5)



Which of the following statements is true?

(A) The titration took place between a strong base and a strong acid

(B) The equivalence point was reached after the addition of 25.0 mL of base

(C) A suitable indicator would be phenolphthalein that changes color at pH = 9

(D) After the addition of 5.00 mL of acid the solution in the flask is a buffer

**ANSWERS**

**1. B**

**2. D**

**3. B**

**4. C**

**5. C**

**6. D**

**7. C**

**8. B**

**9. B**

**10. D**

**SECTION B Free Response Questions (Write answers in the spaces provided)**

**Question 1**

(a) Methanoic acid, a weak monoprotic acid with an acid dissociation constant Ka = 1.77 x 10-4,

is titrated against NaOH, a strong base. A 25.00 mL sample of 0.010 M methanoic acid is

titrated against 0.010 M NaOH. Calculate the volume of NaOH needed to reach the

equivalence point. (2) (8.5)

Moles of acid = (0.02500)(0.010) = 0.00025 = moles of NaOH = (Vol)(0.010)

Vol = 0.025 L

(b) Determine the pH at the following points during the titration. (8.5 & 8.1)

(i) When 12.50 mL of NaOH have been added. (1)

Halfway to the equivalence point, pH = pKa = - log(1.77 x 10-4) = 3.752

(ii) When 25.00 mL of NaOH have been added. (3)

At the equivalence point only the conjugate base is present.

Kb = (Kw)/(Ka) = (1.00 x 10-14)/(1.77 x 10-4) = 5.65 x 10-11

Concentration of the base = (0.00025)/(0.050) = 0.005 M

5.65 x 10-11 = [OH-]2/(0.005)

[OH-] = 5.32 x 10-7

pOH = 6.27

pH = 7.73

(iii) When 30.00 mL of NaOH have been added. (2)

5.00 mL of excess base added. Moles of excess base = (0.005)(0.0100) = 5 x 10-5 moles

[OH-] = (5 x 10-5)/(0.055) = 9.09 x 10-4

pOH = 3.041

pH = 10.96

(c) Select a suitable indicator for the titration from the table below. (1) (8.7)

|  |  |
| --- | --- |
| **Indicator** | **pKa of indicator** |
| Methyl Orange | 3.7 |
| [Methyl Red](https://www.ch.ic.ac.uk/vchemlib/course/indi/ind_mol05.html) | 5.1 |
| [Phenol Red](https://www.ch.ic.ac.uk/vchemlib/course/indi/ind_mol07.html) | 7.9 |
| Phenolphthalein | 9.4 |

Phenol Red

**Question 2 (Based on 1978, 1 and 1988, 7)**

??A 0.682-gram sample of an unknown weak monoprotic organic acid, HA, was dissolved in sufficient water

to make 50 milliliters of solution. This solution was titrated with a 0.135 molar NaOH solution. After the

addition of 10.6 milliliters of base, a pH of 5.65 was recorded. The equivalence point was reached after

the addition of 27.4 milliliters of the NaOH.

(a) Calculate the number of moles of acid in the original sample. (1) (Strictly stoichiometry)

Moles of NaOH = (0.0274)(0.135) = 0.00370 = moles of acid

(b) Calculate the molar mass of the acid. (2) (Strictly stoichiometry)

Moles of acid = 0.00370 = (0.682)/(Molar Mass)

Molar mass = 184 g mol-1

(c) Calculate the value of the ionization constant, Ka, of the acid HA. (3) (8.9)

Moles of NaOH added at 10.6 mL = (0.0106)(0.135) = 0.00143 = moles of conjugate base produced

Moles of acid remaining = [(0.682)/(184)] – (0.00143) = 0.00228

5.65 = - log Ka + log (0.00143/0.00228)

Ka = 1.40 x 10-6

(d) In the space below, *sketch* **and** label a titration curve to show the variation of pH in the titration. (3) (8.5)

Volume of base added on x-axis

pH on y-axis

Curve starts below pH 7

pH = 5.65 after the addition of 10.6 mL of base

Equivalence point is above 7 on y-axis, and at 27.4 mL on x-axis

General shape of curve should be that of a titration curve

(e) Mark a data point X on the curve and write the mathematical expression that could be used as the basis of a calculation to determine the Ka for the acid. (**There is no need to perform any calculation**). (2) (8.5 & 8.9)

X can be anywhere after the addition of any amount of base, all the way up to the equivalence point

pH = pKa + log ([CB]/[HA])

**Question 3 (Based on 2011, 1)**

Consider three solutions all at 25**°**C

**Solution 1:** 25.0 mL of 0.100 M HCl

**Solution 2:** 25.0 mL of 0.100 M NH3

**Solution 3:** 25.0 mL of 0.100 M NH4Cl

Kb for NH3 = 1.80 x 10-5 at 25**°**C

(a) Determine the pH of solution 3. (3) (8.1)

Ka = Kw/Kb = (1.00 x 10-14)/(1.80 x 10-5) = [H3O+]2/(0.100)

[H3O+] = 7.453 x 10-6 M

pH = -log(7.453 x 10-6) = 5.128

(b) (i) Write the net ionic equation for the reaction that occurs in solution 2. (2) (8.3)

NH3 + H2O ⇌ NH4+ + OH-

(ii) Write the Kb expression for the reaction you have written in (b)(i) above. (1) (8.3)

Kb = [OH-]2/[NH3]

(iii) Calculate the [OH**-**] in solution 2. (2) (8.3)

1.80 x 10-5 = [OH-]2/(0.100)

[OH-] = 0.00134 M

(c) The reaction that occurs between HCl and water in solution 1, differs from both of the reactions that occur between NH3 and NH4Cl water in solutions 2 and 3, in one significant manner. Identify that difference and use it to calculate the pH of solution 1. (2) (8.2 & 8.3)

It is 100% to the product side in solution1, since HCl is a strong acid. In solutions 2 and 3 an equilibrium

is established (weak base and weak acid) that is not 100% ionized.

pH = -log (0.100) = 1.000