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| Description: Vertical full colour positive | Safety Bay Senior High School | | | | | |
| **CHEMISTRY UNIT 3 & 4** | | | | | | |
| **Test #2:** | | | | | | |
| **Acids and Bases** | | | | | | |
|  | | | | | | |
| **NAME:** | | |  | | | |
|  | | |  | | | |
| **Time allowed for this paper** | | | | | | |
| Reading time: | | 5 minutes | | | | |
| Working time: | | 50 minutes | | | | |
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| **Structure of this paper:** | | | | | | |
| Section | | | Number of questions | Marks available | | Marks achieved |
| Section One: Multiple Choice | | | 8 | 8 | |  |
| Section Two: Short Answer | | | 8 | 42 | |  |
|  | | |  | | **Total** | \_\_\_\_\_\_ / 50 |

**Section One: Multiple Choice**

Answer all questions by circling the correct option. Only circle one option for each question.

1. The following equation illustrates the reaction between hexaaquairon ion and amide ion:

Fe(H2O)63+(aq) + NH2–(aq) → Fe(H2O)5(OH)2+(aq) + NH3(aq)

Which species in the above equation is acting as a Brønsted-Lowry acid?

* 1. **Fe(H2O)63+ is acting as a Bronsted-Lowry acid.**
  2. NH2– is acting as a Bronsted-Lowry acid.
  3. This is an acid-base reaction, but cannot be explained using Bronsted-Lowry theory.
  4. This is not an acid-base reaction at all.

1. Which of the following species is most likely to be amphiprotic?
   1. **HSO3⁻**
   2. CO32⁻
   3. NH4+
   4. HCℓ
2. Bromocresol green can be used as a chemical indicator. In solution there are two possible forms of the indicator, BCG⁻ and BCG2⁻. The equilibrium between these two species can be represented by the following equation:

|  |  |  |  |
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| BCG2⁻ **(blue)** | + H3O+(aq) ⇌ | BCG⁻ **(yellow)** | + H2O(ℓ) |

Referring to the above equation, what would occur if sodium hydroxide was added to a solution containing bromocresol green?

* 1. **The equilibrium shifts left and the solution would become more blue**
  2. The equilibrium shifts left and the solution would become more yellow
  3. The equilibrium shifts right and the solution would become more blue
  4. The equilibrium shifts right and the solution would become more yellow

1. Three of the following salts form solutions which are approximately neutral. Which salt forms an acidic solution?
   1. Ammonium phosphate (NH4)3PO4
   2. **Ammonium chloride NH4Cℓ**
   3. Ammonium acetate NH4CH3COO
   4. Sodium bromide NaBr
2. Solid sodium acetate is added to water. Which of the following statements best describes what happens?
   1. pH decreases because the acetate ions react with water to produce acetic acid
   2. pH decreases because the sodium ions react with water to produce hydronium ions
   3. **pH increases because the acetate ions react with water to produce hydroxide ions**
   4. pH increases because the sodium ions react with water to produce hydroxide ions
3. Which of the following occurs when a solution changes from pH 9 to pH 12?
   1. The concentration of OH⁻ increases by a factor of 3
   2. The concentration of H3O+ increases by a factor of 3
   3. The concentration of OH⁻ decreases by a factor of 1000
   4. **The concentration of H3O+ decreases by a factor of 1000**
4. Which of the following pairs would form a buffer solution?
   1. **HCOOH(aq) / HCOO⁻(aq)**
   2. HCℓ(aq) / Cℓ⁻(aq)
   3. NH4+(aq) / NO3⁻(aq)
   4. H2SO4(aq) / HSO4⁻(aq)
5. The equation for the auto-ionisation of water is shown below, along with two values for Kw at two corresponding temperatures.

H2O(ℓ) + H2O(ℓ) ⇌ H3O+(aq) + OH-(aq)

Kw = 1.0 x 10-14 at 25 °C

Kw = 2.9 x 10-14 at 40 °C

Considering the information provided, which of the following statements is **not** correct?

* 1. The auto-ionisation of water is an endothermic process.
  2. The concentration of H3O+ in water at 40 °C is higher than water at 25 °C.
  3. The pH of water at 40 °C is lower than water at 25 °C.
  4. **The water at 40 °C is slightly more acidic than water at 25 °C.**

**Section Two: Short Answer**

Write your answers in the spaces provided. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where available.

Suggested working time: 40 minutes

1. **(4 marks)**

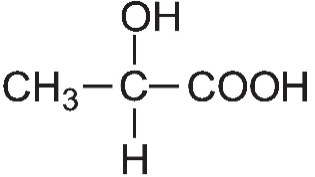
Our understanding of acids and bases has developed over time. One of the earliest attempts to define acids was by French scientist Antoine Lavoisier, who characterised all acids as containing oxygen. This understanding was challenged by the discovery of hydrochloric acid (HCℓ), and lead to the development of newer models.

* 1. English scientist Humphry Davy proposed a new model for acids which could account for the existence of hydrochloric acid. Describe Davy’s understanding of acids, and include an equation to demonstrate the acidity of HCℓ under this model. (2 marks)

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| **Answer** | **Cumulative Marks** |
| Acids are substances that contain hydrogen atoms that can be replaced with metals | 1 mark |
| 2 HCl + Mg 🡪 MgCl2 + H2(g) | 1 mark |
| TOTAL: | 2 marks |

* 1. Davy’s model of acids was surpassed by the Arrhenius model. Describe Arrhenius’s understanding of acids, and include an equation to demonstrate the acidity of HCℓ under this model. (2 marks)

|  |  |
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| **Answer** | **Cumulative Marks** |
| Acids ionise **in solution/when dissolved in water** to produce H+ ions | 1 mark |
| HCl 🡪 H+(aq) + Cl-(aq) | 1 mark |
| TOTAL: | 2 marks |

1.  **(7 marks)**

Lactic acid is a weak organic acid. It is produced naturally through a number of biological reactions, and is found in milk-based food products. The structure of lactic acid is shown to the right.

* 1. When lactic acid dissolves in water it forms lactate ions. Complete the equation showing the ionisation of lactic acid in water. Draw lines linking the conjugate acid-base pairs of the equation, and label each substance as being either an acid or a base. (3 marks)

**Acid**

**Base**

**Base**

**Acid**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | + | H2O | ⇌ |  | + | H3O+ |

|  |  |
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| **Answer** | **Cumulative Marks** |
| In reaction, lactic acid loses a proton and H2O gains a proton | 1 mark |
| Structure of lactate ion is correct. The H removed is from the COOH group | 1 mark |
| Acids and bases labelled correctly with lines joining the pairs | 1 mark |
| TOTAL: | 3 marks |

Solutions of lactic acid and lactate ions exhibit buffering capacity.

* 1. Define buffering capacity. (1 mark)

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| **Answer** | **Cumulative Marks** |
| A measure of the ability of a solution to resist changes in pH  OR  The extent to which a solution can resist changes in pH  OR  How well a solution is able to resist changes in pH | 1 mark |
| TOTAL: | 1 mark |

*Should have some indication that buffering capacity is a measure of the ability to act as a buffer. Should also show understanding of what a buffer actually is!*

*Do not accept ‘ability of a solution to resist changes in pH’ because that if the definition of whether or not a solution is a* ***buffer****, not necessarily* ***buffering capacity****.*

* 1. Account for the ability of a solution of lactic acid and lactate ions to act as a buffer when a few drops of concentrated HCℓ(aq) are added to the solution. (3 marks)

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| **Answer** | **Cumulative Marks** |
| Adding concentrated HCl would increase the concentration of H3O+ (H+) | 1 mark |
| This would cause the reaction shown in part (a) to shift to the left, consuming H3O+ | 1 mark |
| Overall the levels of [H3O+] would remain relatively constant, so pH would stay constant / would not reduce by much | 1 mark |
| TOTAL: | 3 marks |

1. **(6 marks)**

Tartaric acid (C4H6O6) is a common organic acid found in wine. It is classified as a weak, diprotic acid.

* 1. Define the term ‘diprotic’ in relation to Bronsted-Lowry acids and bases. (1 mark)

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| **Answer** | **Cumulative Marks** |
| Can donate two protons | 1 mark |
| TOTAL: | 1 mark |

*Do not accept answers related to Arrhenius theory. e.g. ‘ionises to produce two H+’*

* 1. Write successive ionisation equations to show the ionisation of tartaric acid. Use the Bronsted-Lowry model in your answer. (2 marks)

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| **Answer** | **Cumulative Marks** |
| **First ionisation:**  C4H6O6 + H2O ⇌ C4H5O6⁻ + H3O+ | 1 mark |
| **Second ionisation:**  C4H5O6⁻ + H2O ⇌ C4H4O62- + H3O+ | 1 mark |
| *Only award max 1 mark if equilibrium arrows are not used*  *Deduct 1 mark if Arrhenius theory is used instead of Bronsted-Lowry* | -- |
| TOTAL: | 2 marks |

* 1. How would the pH of a 1 mol L-1 solution of tartaric acid compare to the pH of a 1 mol L-1 solution of nitric acid? Explain. (3 marks)

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| **Answer** | **Cumulative Marks** |
| Nitric acid would have a lower pH than tartaric acid | 1 mark |
| Nitric acid is a strong acid and it fully ionises in solution.  Tartaric acid is a weak acid and only partially ionises in solution. | 1 mark |
| As a result, the nitric acid solution would have a greater concentration of H+/H3O+, and as a result would have a lower pH | 1 mark |
| TOTAL: | 3 marks |

1. **(7 marks)**
   1. Fill in the table to classify the following salts as acidic, neutral or basic.

* Magnesium fluoride MgF2
* Ammonium bromide NH4Br
* Potassium carbonate K2CO3
* Calcium chloride CaCℓ2
* Sodium hydrogenphosphate Na2HPO4
* Strontium nitrate Sr(NO3)2

|  |  |  |
| --- | --- | --- |
| **Acidic** | **Neutral** | **Basic** |
| **NH4Br**  **NaH2PO4** | **CaCl2**  **Sr(NO3)2** | **MgF2**  **K2CO3** |

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| **Answer** | **Cumulative Marks** |
| See table above | 6 x 0.5 marks |
| TOTAL: | 3 marks |

* 1. For each **acidic salt** listed above, write a hydrolysis equation to demonstrate why that salt forms acidic solutions.

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| **Answer** | **Cumulative Marks** |
| NH4+(aq) + H2O(ℓ) ⇌ NH3(aq) + H3O+(aq) | 1 mark |
| H2PO4⁻(aq) + H2O(ℓ) ⇌ HPO42-(aq) + H3O+(aq) | 1 mark |
| TOTAL: | 2 marks |

* 1. For each **basic salt** listed above, write a hydrolysis equation to demonstrate why that salt forms basic solutions.

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| **Answer** | **Cumulative Marks** |
| F⁻(aq) + H2O(ℓ) ⇌ HF(aq) + OH⁻(aq) | 1 mark |
| CO32-(aq) + H2O(ℓ) ⇌ HCO3-(aq) + OH⁻(aq) | 1 mark |
| TOTAL: | 2 marks |

1. **(4 marks)**

The following table shows the hydrolysis equations and acid dissociation constants (Ka) of four weak acids.

|  |  |  |
| --- | --- | --- |
| **Acid** | **Hydrolysis** | **Ka** |
| Iodic acid | HIO3 ⇌ IO3⁻ + H+ | 1.6 x 10-1 |
| Hydrazoic acid | HN3 ⇌ N3⁻ + H+ | 1.9 x 10-5 |
| Hypobromous acid | HBrO ⇌ BrO⁻ + H+ | 2.0 x 10-9 |
| Phenol | C6H5OH ⇌ C6H5O⁻ + H+ | 1.6 x 10-10 |

* 1. Comment on the size of the acid dissociation constant (Ka) for phenol and describe what information this provides about the relative amounts of products and reactants at equilibrium. (2 marks)

|  |  |
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| **Answer** | **Cumulative Marks** |
| Ka is *very* small | 1 mark |
| Indicates amount of products is *much* less than amount of reactants at equilibrium | 1 mark |
| TOTAL: | 2 marks |

* 1. List the formula of the four acids from strongest acid to weakest acid. (1 mark)

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| **Answer** | **Cumulative Marks** |
| HIO3, HN3, HBrO, C6H5OH | 1 mark |
| TOTAL: | 1 mark |

* 1. List the formula of the four conjugate bases from strongest base to weakest base. (1 mark)

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| **Answer** | **Cumulative Marks** |
| C6H5O⁻, BrO⁻, N3⁻, IO3⁻ | 1 mark |
| TOTAL: | 1 mark |

1. **(3 marks)**

500 mL of nitric acid solution, originally at pH 6.0, is diluted by adding an additional 500 mL of water.

Calculate the concentration of H+ and OH- ions in the diluted solution at 25 °C.

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| **Answer** | **Cumulative Marks** |
| [H+]original = 10-pH = 1 x 10-6 mol L-1 | 1 mark |
| After dilution, [H+]dilute = [H+]original / 2 = 0.5 x 10-6 mol L-1 | 1 mark |
| [OH⁻] = Kw / [H+] = 1 x 10-14 / (0.5x10-6) = 2 x 10-8 mol L-1 | 1 mark |
| TOTAL: | 3 marks |

1. **(6 marks)**

Calculate the pH of the solution formed when 6.25 g of solid sodium hydroxide is dissolved into 300 mL of 0.500 mol L-1 hydrochloric acid.

(Assume that the addition of the sodium hydroxide does not affect the volume of the solution.)

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| **Answer** | | **Cumulative marks** |
|  | | 1 |
|  | | 1 |
| ***After neutralisation…*** | | 1 |
| **or** | | 1 |
|  |  | 1 |
| pH = 14 – pOH = 12.3 | pH = -log(H+) = 12.3 | 1 |
|  | | **Total: 6 marks** |

1. **(5 marks)**

Hydrogen tellurite ion (HTeO3⁻) is formed from the ionisation of tellurous acid (H2TeO3). Hydrogen tellurite ion is amphiprotic and can either donate or accept a proton.

The acid hydrolysis equation and acid dissociation expression (Ka) for hydrogen tellurite is shown below.

HTeO3- + H2O ⇌ TeO32- + H3O+

* 1. Write the hydrolysis equation in which hydrogen tellurite ion (HTeO3⁻) acts as a base, and write the base dissociation expression (Kb) for this reaction. (2 marks)

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| **Answer** | **Cumulative Marks** |
| HTeO3⁻ + H2O ⇌ H2TeO3 + OH⁻ | 1 mark |
|  | 1 mark |
| TOTAL: | 2 marks |

* 1. The Ka and Kb for hydrogen tellurite ion were measured at 25 °C.

Ka= 2.0 x 10-8

Kb= 3.3 x 10-12

Would sodium hydrogen tellurite (NaHTeO3) form an acidic, basic or neutral solution when dissolved in water? Justify your answer using the provided information. (3 marks)

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| **Answer** | **Cumulative Marks** |
| A larger K value means more products at equilibrium | 1 mark |
| Ka > Kb (therefore Ka produces more products than Kb) | 1 mark |
| Ka equation produces H3O+, therefore overall result is an acidic solution | 1 mark |
| TOTAL: | 3 marks |