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**CHEMISTRY**

**UNIT 3**

**2018**

**MARKING GUIDE**

**Section One: Multiple-choice (50 marks)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b □ c ■ d □ |  | 11 | a □ b ■ c □ d □ |  | 21 | a □ b ■ c □ d □ |
| 2 | a □ b □ c ■ d □ |  | 12 | a □ b □ c ■ d □ |  | 22 | a □ b □ c ■ d □ |
| 3 | a ■ b □ c □ d □ |  | 13 | a ■ b □ c □ d □ |  | 23 | a □ b ■ c □ d □ |
| 4 | a ■ b □ c □ d □ |  | 14 | a □ b □ c ■ d □ |  | 24 | a □ b □ c ■ d □ |
| 5 | a □ b ■ c □ d □ |  | 15 | a □ b □ c □ d ■ |  | 25 | a □ b □ c □ d ■ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 6 | a □ b □ c □ d ■ |  | 16 | a □ b ■ c □ d □ |  |  |  |
| 7 | a □ b ■ c □ d □ |  | 17 | a □ b □ c □ d ■ |  |  |  |
| 8 | a ■ b □ c □ d □ |  | 18 | a □ b □ c □ d ■ |  |  | (2 marks per question) |
| 9 | a □ b □ c ■ d □ |  | 19 | a □ b ■ c □ d □ |  |  |  |
| 10 | a □ b □ c ■ d □ |  | 20 | a □ b □ c □ d ■ |  |  |  |

**Section Two: Short answer 35% (70 marks)**

**Question 26 (10 marks)**

The first part of an energy profile diagram has been sketched on the axes below.

Products (360 kJ)

Transition state (430 kJ)

Reactants

If the activation energy of the **reverse** reaction is 70 kJ and the heat of reaction (enthalpy change) of the **forward** reaction is 210 kJ mol-1;

(a) Complete the energy profile diagram above. Label the products and the transition state (activated complex). (3 marks)

* **transition state labelled**
* **transition state at 430 kJ**
* **products at 360 kJ**

If a catalyst was added at the start of the reaction;

(b) Which of the following is the **most likely** new value of the activation energy for the **forward** reaction? (circle your answer) (1 mark)

180 kJ 230 kJ 290 kJ

If the temperature of this system was decreased;

(c) Explain, in terms of the collision theory, the effect this would have on the rate of reaction. (3 marks)

* **decreased average kinetic energy of particles**
* **proportion of particles with Ek > Ea is decreased and less frequent collisions occur**
* **reaction rate therefore decreased**

(d) Assuming this is a reversible reaction, what effect would this temperature decrease have on the value of the equilibrium constant, K? Justify your answer. (3 marks)

* **decrease in temp would favour exothermic i.e. reverse reaction**
* **this would increase reactant concentration/decrease product concentration**
* **this would lower the value of K**

**precise**

**Question 27 (10 marks)**

The main buffering system in blood is represented by the equation below:

CO2 (g) + H2O (l) ↔ H2CO3 (aq) ↔ HCO3 -1 (aq) + H3O+ (aq)

Studies of this system have become very important recently, as more people seek to undergo strenuous exercise to gain elite fitness levels. Blood pH must be maintained at a pH of 7.4. The danger of excessive exercise is that if blood pH levels fall below 6.8 or rise above 7.8, death can result.

(a) Considering that strenuous exercise converts blood-glucose into carbon dioxide, which dangerous pH range will this cause the person’s blood to enter?

Circle one of: 6.8 – 7.4 or 7.4 – 7.8 (1 mark)

It is possible to plot a titration curve for this buffer system, where the vertical axis shows the pH of the buffered solution (in this case, the blood). The horizontal axis shows the composition of the buffer: on the left-hand side of the plot, most of the buffer is in the form of carbonic acid or carbon dioxide, and on the right-hand side of the plot, most of the buffer is in the form of bicarbonate ion. (pK = pH)

|  |
| --- |
| http://www.chemistry.wustl.edu/~edudev/LabTutorials/Buffer/images/Titration.jpg |
|  |

(b) The solution is best able to act as a buffer in the pH range of 5.1 to 7.1, as shown on the graph. With reference to the **chemicals** in the buffer, explain why this is the case. (1 mark)

**Carbonic acid ionises to produce hydrogen ions, creating an acidic solution.**

(c) This pH range, especially around the midpoint value of 6.1, enables the buffer to function most effectively. With reference to the **plotted pH curve** on the graph, explain why this is the case.

**The curve is the flattest within this range (1)**

**The movement between % of reactants and products occurs with very small pH changes (1)**

**Therefore the solution is able to resist major pH changes from addition of other chemicals (1)**

As the graph shows, the normal blood pH of 7.4 is outside the optimal buffering range; therefore, chemical changes in the blood due to strenuous exercise may be too great for the buffer alone to effectively control the pH of the blood. When this happens, other organs must help control the amounts of CO2 and HCO3- in the blood.

(d) If the lungs help by removing excess CO2 from the blood, explain (with reference to the buffer equation) how this can alter the pH of the blood. (2 marks)

**[ CO2 ] decreases, causing the eqm to shift to the left (1)**

**This removes some of the H+ ions, increasing the pH (1)**

(e) If the kidneys remove excess HCO3- from the body, explain (with reference to the buffer equation) how this can alter the pH of the blood. (2 marks)

**[ HCO3- ] decreases, causing the eqm to shift to the right (1)**

**This increases the [ H+ ], decreasing the pH (1)**

(f) If blood had a normal pH of 6.1 instead of 7.4, would you expect exercise to result in **heavier** or **lighter** breathing? (Use one highlighted word) (1 mark)

**lighter**

**Question 28**

Examine the diagram below, which shows some of the relevant equations involved in ocean equilibria, specifically the role of carbon-containing species.

**(8 marks)**

**CO32-**

**HCO3-**

**H2CO3**

**CO2**

CO2(g)

*air*

(aq) + H2O(l) (aq) (aq) + H+(aq)

CaCO3(s) Ca2+(aq) + (aq)

*ocean water*

*sediment*

+

H+(aq)

*dissolution*

*precipitation*

(a) Complete the equilibrium equations on the diagram above, by writing the chemical formula of the four (4) missing carbon-containing species in the boxes. (4 marks)

(b) Explain how higher atmospheric carbon dioxide levels cause a decrease in ocean pH, whereas the calcium carbonate present in sediment can counteract this to increase ocean pH. (4 marks)

* **an increase in atmospheric CO2 will increase the concentration of dissolved CO2, carbonic acid and H+ in ocean water (as shown in diagram)**
* **this lowers the pH, since pH = -log [H+]**
* **the CaCO3 present in sediment can dissolve in water, increasing the concentration of CO32- (as shown in the diagram)**
* **this CO32- can react with the H+ in the ocean water, (forming HCO3‑ ) and thereby increasing pH**

**Question 29 (10 marks)**

The ‘etching’ of silicon is performed in the production of semiconductor materials, which are used in all forms of modern technology, such as mobile phones and computers. This etching can be achieved using the reversible chemical reaction below.

Si(s) + 4 HF(g) ⇌ SiF4(g) + 2 H2(g) + heat

(a) Write an equilibrium constant (K) expression for this reaction. (1 mark)

|  |
| --- |
| **K = [SiF4] [H2]2**  **[HF]4** |

(b) Complete the following table, for each of the imposed changes stated. In each case, state the effect on the forward reaction rate and the equilibrium position. (6 marks)

|  |  |  |
| --- | --- | --- |
|  | Forward reaction rate  (increase, decrease, no change) | Equilibrium position  (left, right, no change) |
| Increase in total volume of the system | **Decrease** | **Left** |
| Removal of some H2(g) from system | **Decrease** | **Right** |
| Increase in temperature of the system | **Increase** | **Left** |

(c) Rather than blocks or cubes of silicon (Si), the silicon used in etching is in the form of extremely thin pieces called ‘wafers’. Explain, in terms of the collision theory, what effect this has on both the forward reaction rate and yield of the reaction. (3 marks)

* **forward reaction rate would be increased**
* **increase in surface area will result in a higher rate of reactant collisions**
* **yield will be unaffected by this change as the equilibrium position is not altered**

**Question 30 (10 marks)**

Thymol blue is an indicator that has two distinct colour changes and displays three different colours over the pH range 0 to 14, as shown in the diagram below.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

|  |  |  |
| --- | --- | --- |
| red | yellow | blue |

A few drops of thymol blue were added to the following 0.2 mol L-1 solutions;

* HNO3(aq)
* Mg(NO3)2(aq)
* NH4NO3(aq)
* KHCO3(aq)

(a) Which of these substances is most likely to turn blue? Use an equation to support your answer. (2 marks)

* **KHCO3 has basic pH (due to hydrolysis with water forming OH-ions)**
* **HCO3- + H2O ⇌ H2CO3 + OH‑**

(b) State two (2) solutions that **could not** be distinguished by adding thymol blue. Justify your answer using appropriate chemical equations. (4 marks)

* **NH4NO3 and Mg(NO3)2**
* **NH4NO3 is acidic, NH4+ + H2O ⇌ NH3 + H3O+**
* **Mg(NO3)2 is neutral**
* **Therefore they would both produce a yellow solution in this indicator**

(c) Two forms of thymol blue, at different pH, are shown in the table below. Complete the table, by writing which structure is blue in colour and which is yellow. (1 mark)

|  |  |  |
| --- | --- | --- |
| Thymol blue structure | SO3-  O  HO | SO3-  O  -O |
| Colour  (blue or yellow) | **yellow** | **blue** |

(d) Justify your answer to (c). Include a brief description of how indicators function (i.e. how they are able to change colour). (3 marks)

* **indicators are substances (often weak acids or bases) where the conjugate acid/base species (protonated/deprotonated forms) display a different colour**
* **the structure with the –OH group is the acidic form, having accepted a proton (from the acidic solution it is in)**
* **this would occur at a lower pH, when [H+] is high, and is therefore the yellow form**

**OR**

* **the structure with the –O- group is the basic form, having donated a proton (to the basic solution it is in)**
* **this would occur at a higher pH, when [H+] is low, and is therefore the blue form**

**Question 31 (7 marks)**

Six reactions (A-F) were carried out, as shown in the table below.

|  |  |
| --- | --- |
| A | Zn(s) + Ni(NO3)2(aq) |
| B | Br2(aq) + KI (aq) |
| C | HCl(aq) + KOH(s) |
| D | Br2(aq) + (l) |
| E | Fe(s) + H2O(l) |
| F | Ni(s) + HCl(aq) |

(a) Name the reaction that would occur in E. **rusting / corrosion / oxidation** (1 mark)

(b) In which reaction would halogen displacement occur? **B**  (1 mark)

(c) Write the ionic equation for the reaction occurring in C. (1 mark)

**KOH(s) + H+(aq) → K+(aq) + H2O(l)**

(d) Give full observations for the reaction occurring in A. (2 marks)

* **new silver/grey metal forms as original metal dissolves**
* **green solution fades in colour**

(e) Write two half-equations for the reaction occurring in B. (2 marks)

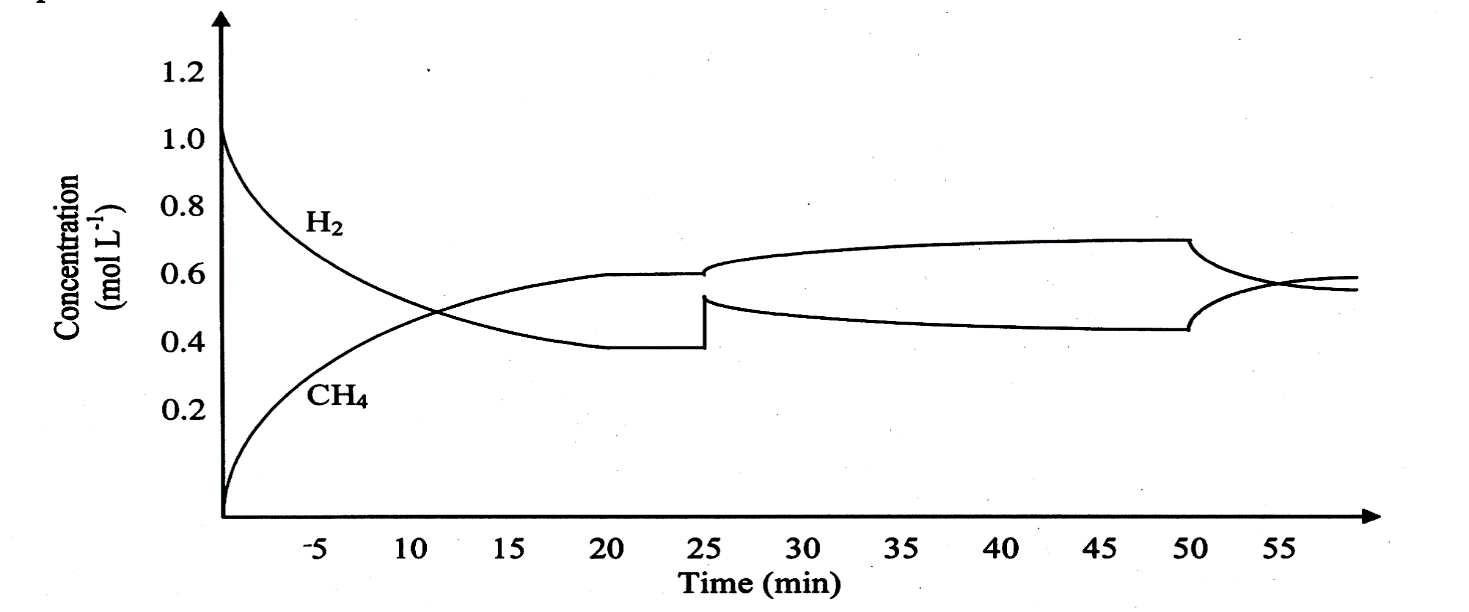
|  |  |
| --- | --- |
| oxidation | **2 I- → I2 + 2 e-** |
| reduction | **Br2 + 2 e- → 2 Br -** |

**Question 32 (8 marks)**

The reaction between carbon and hydrogen gas to form methane can be represented by the following equation:

C(s) + 2H2 (g) ⮀ CH4 (g) + 75 kJ

The concentration of hydrogen and methane was plotted over time and the following graph produced.



(a) About what time was equilibrium first established? (1 Mark)

**20 minutes**

(b) Suggest what could have caused the change at the 25-minute mark. (1 Mark)

**Extra H2 was added / pp of H2 increased / [H2] increased**

(c) Suggest what change occurred at the 50-minute mark. (1 Mark)

**Temperature was increased**

(d) What would be the effect on the equilibrium if more C (s) were added to the system? (1 Mark)

**No effect**

(e) Explain, using Le Chatelier’s Principle, what would be the effect of halving the volume of the reaction container. (4 Marks)

**Halving the volume doubles the pressure on the system (1)**

**The eqm shifts to the right (favours products) (1)**

**To decrease the pressure (as this side has less gas moles) (1)**

**There-by re-establishing eqm (1)**

**Question 33 (7 marks)**

The Arrhenius theory of acids and bases introduced the relationship between acid behaviour and H+(aq) ions. Ethanoic acid (CH3COOH) is a common organic acid found in vinegar. It is a weak, monoprotic acid.

(a) Write an Arrhenius equation for the ionisation of ethanoic acid. (1 mark)

**CH3COOH ⇌ CH3COO- + H+**

(b) Define the term ‘monoprotic’ and explain why ethanoic acid is monoprotic, despite having four (4) hydrogen atoms per molecule. (2 marks)

* **one ionisable/acidic hydrogen atom per molecule**
* **only the H attached to the O is ionised/acidic (also award mark if molecule is drawn with acidic H circled/labelled etc)**

The Bronsted-Lowry theory of acids and bases introduced the concept of the hydronium ion, H3O+(aq), as well as conjugate acid-base pairs.

(c) Explain what the ‘H3O+(aq)’ notation is referring to and why it is often used in preference to the ‘H+(aq)’ notation. (2 marks)

* **refers to the donation of a proton to a water molecule**
* **more accurate representation of what occurs in aqueous solution / displays the conjugate nature and reversibility of acid/base reactions**

(d) Label and link the conjugate acid-base pairs in the equation below. (2 marks)

NO2-(aq) + HSO4-(aq) ⇌ SO42-(aq) + HNO2(aq)

**B A CB CA**

End of Section Two

**Section Three: Extended answer 40% (80 marks)**

**Question 34 (15 marks)**

Iodic acid (HIO3) is found as a white solid at room temperature. It readily dissolves in water to produce an acidic solution, with a solubility of 2.69 kg L-1 at 20 °C. Iodic acid can be used in analytical chemistry to standardise alkaline solutions.

Iodic acid also acts as a strong oxidising agent under acidic conditions. When behaving as an oxidant, it can be reduced to either elemental iodine (I2), iodide ions (I-) or, under the right conditions, to the iodine trichloride dimer (I2Cl6) which is golden yellow in solution.

A solution of acidified iodic acid has some toxic carbon monoxide gas bubbled through it. A brown solution is observed to form, as the carbon monoxide is converted to the less harmful carbon dioxide gas.

(a) Write the oxidation and reduction half-equations and the overall redox equation for this reaction. (3 marks)

|  |  |
| --- | --- |
| Oxidation half-equation | **CO + H2O → CO2 + 2 H+ + 2 e-** |
| Reduction half-equation | **2 HIO3 + 10 H+ + 10 e- → I2 + 6 H2O**  **OR**  **2 IO3- + 12 H+ + 10 e- → I2 + 6 H2O** |
| Overall redox equation | **5 CO + 2 HIO3 → 5 CO2 + I2 + H2O**  **OR**  **5 CO + 2 H+ + 2 IO3- → 5 CO2 + I2 + H2O** |

A chemistry student is experimenting with iodic acid, to investigate some of its physical and chemical properties. She wants to determine the strength of the acid, but cannot find any information about the acidity constant (Ka) of iodic acid in her research.

(b) Write an acidity constant expression for iodic acid and explain what information a Ka value would provide regarding the acid. (2 marks)

* **Ka = [H3O+/H+] [IO3- ]**

**[HIO3]**

* **Value indicates extent to which acid ionises (i.e. strength of acid)**

One method used to prepare iodic acid is by reacting aqueous iodine with aqueous chlorine. This produces a mixture of iodic and hydrochloric acids, as shown in the equation below;

I2(aq) + 5 Cl2(aq) + 6 H2O(l) → 10 HCl (aq) + 2 HIO3(aq)

(c) Identify the oxidising agent (oxidant) and reducing agent (reductant) in this reaction. Use oxidation numbers to support your answer. (4 marks)

* **I2 is reducing agent**
* **O.N. from 0 to +5 (oxidation)**
* **Cl2 is oxidising agent**
* **O.N. from O to -1 (reduction)**

The chemistry student decided to prepare a sample of iodic acid according to the reaction above. She mixed 750 mL of 2.15 x 10-3 mol L-1 aqueous iodine (I2) with 830 mL of chlorine water (Cl2) in a large beaker. Once the reaction had finished, a mixture of iodic and hydrochloric acids was present. She used a digital pH meter to measure the resulting pH of the solution and determined it to be 1.98.

(d) Determine and justify whether iodic acid is a strong or weak acid. Use appropriate calculations to support your answer. (You may assume that the chlorine water was in excess and that the reaction went to completion, consuming all of the iodine.) (6 marks)

**n(I2) = cV**

**= 2.15 x 10-3 x 0.75**

**= 1.6125 x 10-3 mol**

**if both acids are strong, then**

**n(H+ total produced) = 12 x n(I2)**

**= 0.01935 mol**

**C(H+ total) = n/V**

**= 0.01935 / 1.580**

**= 0.012247 mol L-1**

**pH = -log[H+]**

**= -log 0.012247**

**= 1.912**

**pH of 1.98 is > than 1.912 i.e. pH is less acidic than maximum possible**

**therefore iodic acid is weak (also accept moderate / moderately strong – just not ‘strong’!)**

**OR**

**If pH is 1.98; [H+] = 1.047 x 10-2 mol L-1 (1)**

**then n(H+ total) = cV = 1.047 x 10-2 x 1.580 = 0.01654 mol (1)**

**compare this to n(H+ total produced if both acids strong) = 0.01935 mol (2, see above)**

**Then can deduce that total moles actually present is less than theoretical moles if both acids are strong. Since HCl is a strong acid, iodic acid can’t be. (2)**

**Question 35 (15 marks)**

Dichlorine monoxide (Cl2O) is a brownish-yellow gas at room temperature. It is very soluble in water and when dissolved, it reacts with water to produce weak hypochlorous acid, according to the reversible reaction below;

Cl2O(g) + H2O(l) ⇌ 2 HOCl(aq)

The solution of hypochlorous acid appears colourless. At room temperature (298 K) this reaction has a Kc value of 0.090.

H2O(l)

Cl2O

gas

A sample of Cl2O(g) was injected into a glass cylinder containing water, as shown in the diagram to the right, and allowed to establish equilibrium according to the equation above.

Several graphs have been sketched below, in an attempt to show the changes in concentration of Cl2O(g) and HClO(aq) from Time 0, when the gas was injected into the system, until equilibrium was first established at Time E1. You may assume the scales on both axes of each graph are identical.

(a) Which of these graphs (A, B or C) is **most likely** to illustrate the concentration changes that would occur, from the time the Cl2O(g) is injected into the system until the time that equilibrium is established at E1? Explain your choice below. (3 marks)

* **graph C**
* **the final [HClO] < [Cl2O], this reflects the K value being lower than 1**
* **the gradient of HClO is twice that of Cl2O, this reflects the 2:1 stoich ratio**

Then, at some point after E1, the pressure on the system was then increased, as shown in the diagram below.

Cl2O(g)

H2O(l) / HOCl(aq)

Cl2O(g)

H2O(l) / HOCl(aq)

(b) State the effect this would have on the equilibrium position and describe any corresponding observations that would be made as a result of this imposed change. (3 marks)

* **favour forward reaction / favour products**
* **browny yellow gas colour above solution will initially darken as pressure increased**
* **then gas colour will lighten as equilibrium is re-established**

(c) Explain what would happen to both the forward and reverse reaction rates, from the time the pressure was increased until the system re-establishes equilibrium. (3 marks)

* **the forward and reverse reaction rates would increase, due to increased particle collision (forward would have instantaneous increase, reverse instantaneously no change, then an increase, since no gas particles on the products side – students don’t need this much detail to get the mark though)**
* **the forward reaction rate would increase more, as this converts 1 gas mol to 0 gas mol, thereby counteracting the imposed change**
* **at E2 the reaction rates are again equal, but higher, than original**

When the temperature of this equilibrium system is increased to 400 K, the new value of K is 1.98.

(d) Explain what information this provides about the heat of reaction (ΔH), including details of how you arrived at that conclusion. (3 marks)

* **an increased K value means an increase in product concentration (since K = P/R)**
* **this means the forward reaction must have been favoured**
* **this means the forward reaction is endothermic i.e. ΔH positive**

**(a temp increase always favours the endo direction)**

(e) Continue the graph below, showing the effect of a temperature increase on the system (imposed at Time Y) until equilibrium is re-established at E3. (You may assume water is still in the liquid state, as a result of the previous pressure increase.) (3 marks)

Cl2O(g)

HClO(aq)

**graphs must cross over (1)**

**HClO must increase 2x the units that Cl2O decreases (1)**

**lines must become horizontal at E3 (1)**

**Question 36 (19 marks)**

Powdered baby formula (milk powder) must be manufactured according to very strict specifications, to ensure it contains the correct nutritional balance to sustain the healthy growth of a baby. By law, whole milk powder for babies must contain a minimum of **26.44 g of protein per 100 g of milk powder**.

A sample of powdered baby formula was analysed for quality control purposes to determine the protein content. 3.75 grams of dairy milk powder was dissolved in 50.00 mL of sulfuric acid. The ammonium sulfate formed was distilled and the liberated ammonia gas was then captured and absorbed into 75.00 mL of a 0.200 mol L-1 boric acid solution.

Three 20.00 mL aliquots of the captured boric acid solution were then titrated against a standard 0.0650 mol L-1 sodium carbonate solution. The results of the titration are shown in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1 | 2 | 3 |
| Initial reading (mL) | 48.30 | 33.15 | 17.95 |
| Final reading (mL) | 33.15 | 17.95 | 2.75 |
| Titre (mL) | **15.15** | **15.2** | **15.2** |

(a) Use the titration results to calculate the number of moles of excess B(OH)3 remaining in the 75.00 mL sample **after** the capture of NH3. (4 marks)

**average titre = 15.1833 mL**

**n(Na2CO3) = cV**

**= 0.0650 x 0.015833**

**= 9.8692 x 10-4 mol**

**n(B(OH)3 in 20 mL aliquot) = n(Na2CO3)**

**n(B(OH)3 in 75 mL) = 9.8692 x 10-4 x (75 / 20)**

**= 3.7009 x 10-3 mol**

**= 3.70 x 10-3 mol (3SF)**

(b) Use your answer from (a), as well as the **original** concentration of B(OH)3, to calculate the number of moles of NH3 that was captured in the boric acid solution. (3 marks)

**n(B(OH)3 originally) = cV**

**= 0.200 x 0.07500**

**= 0.015 mol**

**n(B(OH)3 used to capture NH3) = n(original B(OH)3) – n(remaining B(OH)3)**

**= 0.015 - 3.7009 x 10-3**

**= 0.0112991 mol**

**n(NH3 captured) = n(B(OH)3) = 0.0113 mol (3SF)**

(c) Calculate the percent composition (by mass) of nitrogen in the sample of powdered baby formula. Express your answer to the correct number of significant figures. (4 marks)

**n(N) = n(NH3)**

**m(N) = nM**

**= 0.0112991 x 14.01**

**= 0.1583 g**

**% N in powder = 0.1583 / 3.75 x 100**

**= 4.2213%**

**= 4.22 % (3 SF)**

**(1m has been included here for stating answers to correct SF,**

**only lose 1 mark in total for incorrect SF, not 1m per Q)**

(d) Use the appropriate conversion factor to calculate the protein content in the baby formula, and comment on whether this batch of milk powder meets the minimum requirement for protein content. (2 marks)

**protein content = m(N) x dairy conversion factor**

**= 0.1583 x 6.38**

**= 1.009954 g**

**i.e. 1.009954 g of protein in the 3.75 g sample of milk powder used**

**therefore 1.009954 x (100/3.75)**

**= 26.93 g per 100 g of milk powder**

**OR**

**protein content = %N (already in g per 100 g) x dairy conversion factor**

**= 4.22 x 6.38**

**= 26.93 g protein in 100 g milk powder**

**Yes, this meets the requirements of 26.44 g per 100 g milk powder**

As outlined previously, the back titration in the Kjeldahl method is performed using a sodium carbonate primary standard as well as the indicator methyl orange.

(e) Define the term ‘standard solution’ and state two (2) characteristics of Na2CO3 that allow it to be used as a primary standard. (3 marks)

* **standard solution is one that has known concentration**
* **high molecular weight, high purity, soluble in water, reacts according to known equations, not deliquescent etc (any 2 relevant characteristics, 1m each)**

If the burette had been rinsed with distilled water at the start of the experiment;

(f) What effect would this error have on the value of the titre volumes obtained (i.e. higher volumes, lower volumes or unaffected)? (1 mark)

* **higher volumes**

(g) Is this a random or systematic error? Explain your answer. (2 marks)

* **systematic error**
* **this is an incorrect technique, so error can be minimised by using correct scientific technique (systematic errors always give consistently high/low results)**

**Question 37 (16 marks)**

Hydrogen Peroxide (H2O2) is a chemical that undergoes “disproportionation” or self-redox, meaning it can be oxidised and reduced at the same time.

(a) Complete the following table with the balanced half-equations and full redox equation, if the two products of hydrogen peroxide disproportionation are water and oxygen gas. (3 marks)

|  |  |
| --- | --- |
| Reduction  Half-Equation | **H2O2 + 2H+ + 2e- → 2H2O** |
| Oxidation  Half-Equation | **H2O2 → O2 + 2H+ + 2e-** |
| Working space |  |
| Redox Equation | **2H2O2 → 2H2O + O2** |

Hydrogen Peroxide (H2O2) is a chemical that has many uses, including being used in aqueous solution as a hair bleaching agent, in a “20-volume” strength.

The volume strength refers to the litres of oxygen gas produced at STP when 1L of hydrogen peroxide solution disproportionates into water and oxygen gas (according to the equation above).

(b) Calculate the moles of oxygen gas that corresponds to the amount produced when 1L of

**20-volume** hydrogen peroxide disproportionates. (2 marks)

**20-volume H2O2 means 20L of O2 gas is produced.**

**n = 20 / 22.71 = 0.8807 mol**

(c) Using the balanced redox equation from (a) above, calculate the moles of hydrogen peroxide that is required to produce this amount of oxygen gas. (1 mark)

**n(H2O2) = 2 x 0.8807 = 1.761 mol**

(d) Calculate the concentration (in mol L-1) of this hydrogen peroxide solution. (1 mark)

**c(H2O2) = 1.761 / 1 = 1.761 molL-1**

(e) Calculate the concentration (% by mass) of this hydrogen peroxide solution, given that the density of a 20-volume solution is 1.02 gmL-1. (4 marks)

**n(H2O2) = 1.761 x 1 = 1.761 mol**

**m(H2O2) = 1.761 x 34.016 = 59.90 g**

**m(solution) = 1.02 x 1000 = 1020 g**

**%(H2O2) = 59.90 / 1020 x 100 = 5.873%**

(f) A hairdresser wants to prepare 5L of 20-volume hydrogen peroxide solution from a concentrated (27.5% by mass, density of 1.13 gmL-1) stock solution that the salon buys in bulk. Calculate the volume of the concentrated stock solution she would need to measure out to prepare the desired 20-volume solution. (5 marks)

**m(solution) in 1L = 1000 x 1.02 = 1020 g**

**m(solution)20vol  in 5L = 5 x 1020 = 5100 g**

**m(H2O2)20vol  in 5L = 5100 x 5.873/100 = 299.523 g**

**m(H2O2)stock  in 1mL = 27.5/100 x 1.13 = 0.31075 g**

**V(H2O2)stock  = 299.523 / 0.31075 = 963.87 mL**

**Question 38 (15 marks)**

A chemistry student was investigating what type of solutions can be mixed together to form a buffer.

Firstly, he made two different hydrogensulfate / sulfate buffers. As illustrated in the diagrams below, one beaker contained a 1 L mixture of 0.5 mol L-1 NaHSO4(aq) and 0.5 mol L-1 Na2SO4(aq). The second beaker contained a 1 L mixture of 0.1 mol L-1 NaHSO4(aq) and 0.1 mol L-1 Na2SO4(aq).

0.1 mol L-1 HSO4-

mixed with

0.1 mol L-1 SO42-

0.5 mol L-1 HSO4-

mixed with

0.5 mol L-1 SO42-

Unfortunately, the student forgot to label the beakers, and could not remember which was which.

(a) Explain how the student could experimentally determine which beaker contained which buffer. Include a description of buffering capacity in your answer. Assume you have access to standard laboratory reagents and equipment. (6 marks)

* **buffering capacity is a measure of the extent to which a buffer can resist changes in pH as small amounts of strong acid or base are added to it**

**to distinguish the solutions;**

* **add either strong acid or base drop wise to each beaker**
* **monitor pH using pH meter**
* **when buffer has a drastic change in pH this shows buffering capacity has been exceeded**
* **the beaker which has less acid/base added to cause this sudden change can be identified as the 0.1/0.1 buffer OR the beaker which has more acid/base added to cause this sudden change can be identified as the 0.5/0.5 buffer**
* **since 0.1/0.1 buffer has lower absolute concentrations of the conjugate acid/base species it will have the lower buffering capacity OR since 0.5/0.5 buffer has higher absolute concentrations of the conjugate acid/base species it will have the higher buffering capacity**

Next, the student decided to mix together solutions of sodium hydroxide, NaOH, and barium hydroxide, Ba(OH)2.

NaOH

mixed with

Ba(OH)2

(b) Why doesn’t this solution form a buffer? (1 mark)

* **these solutions do not contain conjugate species / both are strong bases**

The original sodium hydroxide solution had a pH of 9.9 and the student measured 850 mL of this into a beaker. He then added 95.0 mL of a 0.075 mol L-1 barium hydroxide solution to the same beaker.

(c) Calculate the pH of the resulting solution. (8 marks)

**[H+ in NaOH] = 10-pH**

**= 10-9.9**

**[OH- in NaOH] = (1.0 x 10-14) / 10-9.9**

**= 7.94328 x 10-5 mol L-1**

**n(OH- in NaOH) = cV**

**= 7.94328 x 10-5 x 0.850**

**= 6.75179 x 10-5 mol**

**n(OH- in Ba(OH)2) = 2x n(Ba(OH)2)**

**= 2 x (0.075 x 0.0950)**

**= 0.01425 mol**

**n(OH- total) = 6.75179 x 10-5 + 0.01425**

**= 0.0143175 mol**

**C(OH- total) = n/V**

**= 0.0143175 / 0.945**

**= 0.0151508 mol L-1**

**[H+ total] = (1.0 x 10-14) / 0.0151508**

**= 6.6003 x 10-13 mol L-1**

**pH = -log 6.6003 x 10-13**

**= 12.18**

**= 12 (2 SF)**

End of questions