STAV

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CHEMISTRY
Unit 4
Trial Examination

SOLUTIONS BOOK

Use this page as an overlay for marking the multiple choice answer sheets. Simply photocopy the page onto an overhead projector sheet. The correct answers are open boxes below. Students should have shaded their answers. Therefore, any open box with shading inside it is correct and scores 1 mark.

	ONE ANSWER PER LINE		ONE ANSWER PER LINE
1	■■■■ ☐	11	■■■ ☐ ■
2	☐ ■■■■■	12	☐ ■■■■■
3	■■■■ ☐	13	■■■ ☐ ■
4	■■■ ☐ ■	14	■■■■■ ☐
5	☐ ■■■■■	15	■■■■■ ☐
6	■ ☐ ■■■	16	☐ ■■■■■
7	■■■■ ☐ ■	17	■ ☐ ■■■
8	■■■■ ☐ ■	18	☐ ■■■■■
9	■ ☐ ■■■	19	☐ ■■■■■
10	■ ☐ ■■■	20	■ ☐ ■■■

SECTION A (Total 20 marks)

1.	D	2.	A	3.	D	4.	C	5.	A
6.	B	7.	C	8.	C	9.	B	10.	B
11.	C	12.	A	13.	C	14.	D	15.	D
16.	A	17.	B	18.	A	19.	A	20.	B

Discussion of Section A answers

Question 1
The surface of a catalyst bonds with the reacting molecules to weaken the existing bonds within the reacting molecules and thereby lower activation energy. **Correct answer is D.**

Question 2
An increase in pressure results in this particular equilibrium shifting in the forward direction to partially oppose the change (LCP) as there are less molecules on the right. The equilibrium yield therefore increases.
Increased pressure increases rate. Particles are squeezed into a smaller volume meaning that there will be more particles per unit volume and therefore more successful or 'fruitful' collisions per unit time. ·
Correct answer is A.

Question 3
All 3 statements are true. **Correct answer is D.**

Question 4
In reaction 2, the Cr^{2+} atoms are being oxidised to Cr^{3+} and the H^+ is reduced to H_2.
In reaction 3, the C atoms are being oxidised to CO and the Cr atoms in Cr_2O_3 are reduced to Cr.
Reactions 2 and 3 are both redox reactions. **Correct answer is C.**

Question 5
Only equation I involves proton transfer. **Correct answer is A.**

Question 6
Water self ionises. **Correct answer is B.**

Question 7
$K = [C_2H_6] / ([C_2H_4] [H_2]) = (1.25 \times 10^{-1}) / 0.5 \div [(7.50 \times 10^{-2} / 0.5) \times (8.35 \times 10^{-2} / 0.5)] = 9.98$
Correct answer is C.

Question 8
Only temperature can permanently change the concentration fraction. **Correct answer is C.**

Question 9
As temperature decreases, the equilibrium shifts in the direction that produces heat i.e. net forward reaction for this equilibrium system. $[H^+]$ decreases so therefore the pH increases.
Correct answer is B.

Question 10
As $[CO_2]$ increases, the equilibrium shifts in the direction that removes some of the $[CO_2]$ causing a net forward reaction for this equilibrium system. $[H^+]$ increases so therefore the pH decreases.
Correct answer is B.

Question 11
A catalyst does not change the position of equilibrium it just allows a reaction to reach equilibrium faster.
At equilibrium, the rate of the forward reaction equals the rate of the back reaction. **Correct answer is C.**

Question 12

A methanol fuel cell would produce CO_2 - a greenhouse gas. (It is possible to reverse the fuel cell reaction to regenerate the methanol but this process would require electricity which currently is produced primarily from coal here in Australia.) **Correct answer is A.**

Question 13

CH_3OH is oxidised to CO_2 (carbon atoms change oxidation number from -2 to +4). Hence methanol is the reductant and is oxidised at the anode (reduction occurs at the cathode in **any** electrochemical cell) **Correct answer is C.**

Question 14

No discussion required. **Correct answer is D.**

Question 15

A decrease in volume causes an increase in pressure. An increase in pressure results in this particular equilibrium shifting in the forward direction to partially oppose the change (LCP) as there are less molecules on the right. The amount of N_2O_4 therefore increases. **Correct answer is D.**

Question 16

The given equilibrium is exothermic. An increase in temperature results in this particular equilibrium shifting in the reverse direction to partially oppose the change (LCP) and lower the temperature. The equilibrium yield of N_2O_4 therefore decreases. **Correct answer is A.**

Question 17

$K = [N_2O_4] / [NO_2]^2$ Therefore $[N_2O_4] = K \times [NO_2]^2 = 0.010 \times [NO_2]^2$ **Correct answer is B.**

Question 18

$n(Al) = 1/27 = 3.7 \times 10^{-2}$ mol; $n(e) = 3 \times n(Al) = 3 \times 3.7 \times 10^{-2} = 1.11 \times 10^{-1}$ mol
$n(Mg) = 1/24.3 = 4.12 \times 10^{-2}$ mol; $n(e) = 2 \times n(Mg) = 2 \times 4.12 \times 10^{-2} = 8.24 \times 10^{-2}$ mol
$n(Na) = 1/23 = 4.34 \times 10^{-2}$ mol; $n(e) = n(Na) = 4.34 \times 10^{-2} = 4.34 \times 10^{-2}$ mol
$n(Cl_2) = 1/71 = 1.41 \times 10^{-2}$ mol; $n(e) = 2 \times n(Cl_2) = 2 \times 1.41 \times 10^{-2} = 2.82 \times 10^{-2}$ mol

The largest $n(e)$ is for Al. **Correct answer is A.**

Question 19

According to the electrochemical series, under standard conditions, Cu would be deposited first, followed by Zn. Potassium cannot be produced by electrolysis of K+ ions in water as the water is preferentially reduced. **Correct answer is A.**

Question 20

H_2O would be oxidised to O_2 at the anode and H_2O is reduced to H_2 at the cathode. **Correct answer is B.**

SECTION B – Short answer questions

Question 1 (6 marks)

a. $Cl_2(aq) + 2OH^-(aq) \rightleftharpoons Cl^-(aq) + ClO^-(aq) + H_2O(l)$
Cl atoms in Cl_2 are in oxidation state 0,
in Cl^- the atoms are in oxidation state -1 **(1 mark)** and in ClO^- are in oxidation state +1 **(1 mark)**
therefore some chlorine atoms have been oxidised and some Cl atoms have been reduced.

b. The reducing agent or reductant will be oxidised. **(1 mark)** This means an increase in oxidation number for the species. Cl^- is the reducing agent in the reverse direction as its oxidation number increases from -1 to 0. **(1 mark)**

c. An increase in $[Cl_2]$ results in this particular equilibrium shifting in the forward direction to partially oppose the change (LCP). **(1 mark)** This causes the $[OH^-]$ to decrease. The mixture becomes less basic therefore pH decreases. **(1 mark)**

Question 2 (9 marks)

a. $K_c = [Z]^2 / [X]^2[Y]$ **(1 mark)**

b. $M^2/M^3 = M^{-1}$ **(1 mark)**

c. Concentration fraction $= 2^2 / (2^2 \times 2) = 0.5$ **(1 mark)** $\neq 4$
Therefore the mixture is not at equilibrium. **(1 mark)**

d. $[2/x]^2 / ([2/x]^2[2/x]) = 4$ **(1 mark)** $x/2 = 4 \therefore x = 8$ i.e. 8 Litres **(1 mark)**

e. An increase in V results in a overall decrease in concentration. In this particular equilibrium, there would be a net back reaction to partially oppose the change (LCP) by creating more particles to increase the overall number of particles. **(1 mark)**
This causes the number of mole of Y to increase **(1 mark)** but the overall concentration of Y decreases because of the initial dilution. **(1 mark)**

Question 3 (6 marks)

a. $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$ **(1 mark)**

b. i. $C_6H_{12}O_6(aq) + 6H_2O(l) \rightarrow 6CO_2(g) + 24H^+(aq) + 24 e^-$ **(1 mark)**

ii. $C_6H_{12}O_6(aq) + 12H^+(aq) + 12 e^- \rightarrow 3C_2H_5OH(aq) + 3H_2O(l)$ **(1 mark)**

c. i. $\Delta T = 30.5 - 20.0 = 10.5\,°C$

$\Delta E = mc\Delta T = (100 \times 1000) \times 4.18 \times 10.5 = 4389 \times 10^3\,J = 4.39\,MJ$ **(1 mark)**

ii. M (glucose) $= 180.0\,g\,mol^{-1}$

n (glucose) $= m/M = 11.5 \times 1000 \div 180.0 = 63.89\,mol$ **(1 mark)**

Hence 1 mol releases $4389 \div 63.89 = 68.70\,kJ$ Therefore $\Delta H = -68.7\,kJ\,mol^{-1}$ **(1 mark)**

Question 4 (5 marks)

When the two different metals sitting in a solution containing ions are connected, a galvanic cell is set up and the more reactive metal, Ni, passes electrons on to the less reactive metal, Cu. **(1 mark)**

(alternatively a student may argue that nickel is a stronger reductant than copper and is preferentially oxidised)

$Ni\ (s) \rightarrow Ni^{2+}(aq)\ + 2e^-$ **(1 mark)**
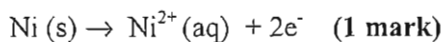
These electrons are then passed onto H^+ ions at the surface of the copper causing H_2 to form.

$2H^+(aq)\ +\ 2e^-\ \rightarrow\ H_2\ (g)$ **(1 mark)**
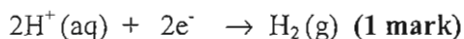
When the two metals are not connected, but just sit in the acid, nickel will react with the H^+ ions at the surface of the nickel causing H_2 to form. **(1 mark)**

or $Ni\ (s)\ +\ 2H^+(aq)\ \rightarrow\ Ni^{2+}(aq)\ +\ H_2\ (g)$
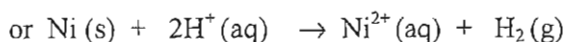
The Cu cannot react with the H^+ ions under these conditions as it is a weaker reductant. **(1 mark)**

Question 5 (7 marks)

a. $CH_3CH(OH)COOH\ +\ H_2O\ (l) \rightleftharpoons H_3O^+\ (aq)\ +\ CH_3CH(OH)COO^-(aq)$ **(1 mark)**

b. $K_a\ =\ [CH_3CH(OH)COO^-]\ [H_3O^+]\ /\ [CH_3CH(OH)COOH\ ]$ **(1 mark)**

c. $[CH_3CH(OH)COO^-]\ /\ [CH_3CH(OH)COOH\ ]\ =\ 0.037$ **(1 mark)**

      but $[CH_3CH(OH)COOH\ ]\ =\ 0.0900$ assuming the % ionisation is small.

      $[CH_3CH(OH)COO^-]\ =\ 0.037\ x\ 0.0900\ =\ 3.3\ x\ 10^{-3}\ M$ **(1 mark)**

      $[CH_3CH(OH)COO^-]\ =\ [H_3O^+]$ **(1 mark)**

      $K_a\ =\ (3.3\ x\ 10^{-3})^2\ /\ 0.090\ =\ 1.2\ x\ 10^{-4}$ **(1 mark)**

d. $H^+(aq)\ +\ HCO_3^-\ (aq) \rightleftharpoons H_2O\ (l)\ +\ CO_2\ (g)$ **(1 mark)**

Question 6 (7 marks)

a.   i. $Pb(s)\ +\ SO_4^{2-}(aq) \rightarrow PbSO_4(s)\ +2e^-$ **(1 mark)**

      ii. $PbO_2\ (s)\ +\ 4H^+\ (aq)\ +\ SO_4^{2-}(aq)\ +\ 2e^-\ \rightarrow\ PbSO_4\ (s)\ +\ 2\ H_2O\ (l)$ **(1 mark)**
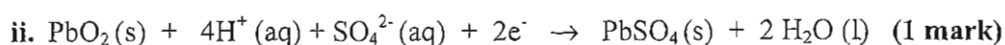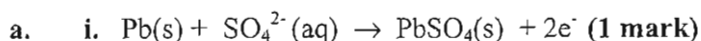
b. PbO_2 is the cathode **(1 mark)**

c.   The negatively charged $SO_4^{2-}(aq)$ **(1 mark)**

d.   The difference can be explained because the battery has a approximately 4M H_2SO_4 (aq) electrolyte which is not standard. **(1 mark)**

e. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$ **(1 mark)**

f. As the battery is producing energy the acid is being used up and therefore the density of the acid decreases. **(1 mark)**

Question 7 (5 marks)

a. $pH = -\log_{10}[H^+] = -\log_{10} 0.10 = 1.0$ **(1 mark)**

b. Sulfuric acid has the lower pH as it has two protons to donate with the first ionisation being virtually complete just as it is for hydrochloric acid. **(1 mark)**

c. Ethanoic acid is a **weak** monoprotic acid and therefore the $[H^+]$ in an equimolar solution is very much lower and therefore the pH is significantly higher. **(1 mark)**

d. When both solutions are diluted, the pH increases. However, because ethanoic is a weak acid the dilution causes a net forward reaction **(1 mark)** to produce more H^+ and therefore the pH increase is less than for the strong acid. **(1 mark)** Therefore the hydrochloric acid increases in pH by 2 units but the change is less than 2 for ethanoic acid.

Question 8 (9 marks)

a. i. In an energy producing device, the anode is the site of oxidation (loss of electrons). **(1 mark)** Since the H_2 gas is losing electrons the reaction occurs at the anode. **(1 mark)**

   ii. electrical energy into chemical energy **(1 mark)**

b. $CH_3OH + H_2O \rightarrow CO_2 + 3H_2$ **(1 mark)**

c. i. From the data book
   Hydrogen: 286 kJ mol^{-1} = 286 / 2.0 kJ g^{-1} = 143 kJ g^{-1} **(1 mark)**
   Methanol: 725 kJ mol^{-1} = 725 / 32.0 kJ g^{-1} = 22.7 kJ g^{-1} **(1 mark)**

   ii. hydrogen gives more than 6 times greater energy per gram than methanol **(1 mark)**

d. Methanol has the polar –OH group **(1 mark)** and can form hydrogen bonds with water. **(1 mark)**

Question 9 (11 marks)

a.   Iron electrode (is the site of reduction). **(1 mark)**

b.

Iron	$2H^+ (l) + 2e^- \rightarrow H_2 (g)$ **(1 mark)**
	(or $2HF (l) + 2e^- \rightarrow H_2 (g) + 2F^- (l)$
Carbon	$2F^- (l) \rightarrow F_2 (g) + 2e^-$ **(1 mark)**
	(or $2HF (l) \rightarrow F_2 (g) + 2H^+ (l) + 2e^-$)

Deduct one mark for incorrect states. **Reactants must not be (aq).**

c.   The fluoride ion is a weaker reductant than water. **(1 mark)**. Therefore water would be oxidised in preference producing O_2 and H^+ according to the equation:

$2H_2O (l) \rightarrow O_2 (g) + 4H^+ (aq) + 4e^-$ **(1 mark)**

Alternatively, could give: $2H_2O (l) \rightarrow O_2 (g) + 2H_2 (g)$

d.   Iron is a **stronger reductant** than the fluoride ion and would be oxidised in preference. **(1 mark)**

e.   **i.** $Q = It = 10.5 \times 10 \times 60 = 6300$ C $(6.3 \times 10^3$ C) **(1 mark)**

$n(e) = \dfrac{Q}{F} = \dfrac{6300}{96500} = 0.06528$ mol (assuming 100% efficiency) **(1 mark)**

Amount of electrons discharging fluorine gas is $n(e)_{used}$

Therefore: $n(e)_{used}$ is 90% of $0.06528 = 0.05876$ mol **(1 mark)**

$n(F_2) = \frac{1}{2} n(e)_{used} = \frac{1}{2} \times 0.05876 = 0.02938$ mol **(1 mark)**

ii. $V(F_2) = n \times V_m = 0.02938 \times 24.5 = 0.72$ L   **(1 mark)**

END OF SUGGESTED SOLUTIONS