SCIENCE TEACHERS ASSOCIATION VICTORIA 2024

TRIAL EXAMINATION

SOLUTIONS BOOK

CHEMISTRY
UNIT 3

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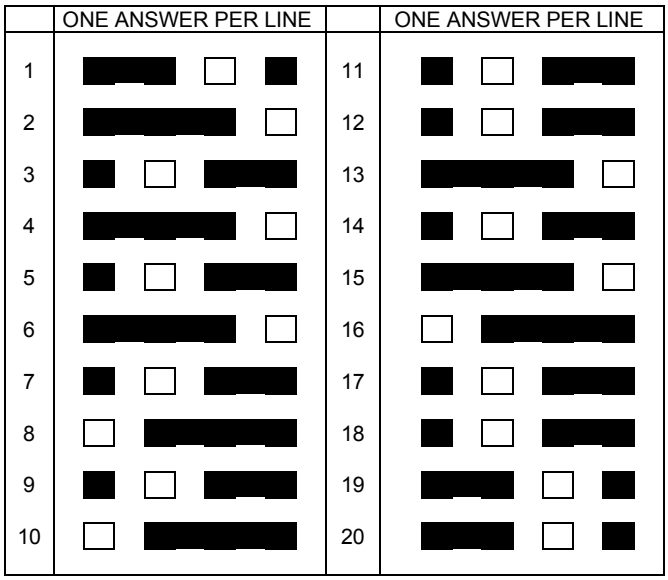
Use this page as an overlay for marking the multiple choice answer sheets. Simply photocopy the page onto an overhead projector sheet. The correct answers are open boxes below. Students should have shaded their answers. Therefore, any open box with shading inside it is correct and scores 1 mark.



SECTION A (Total 20 marks)

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

Comments for Section A answers

Question 1
Biogas is a renewable resource and is produced by anaerobic breakdown of organic matter by bacteria.
Correct Answer: C

Question 2
At SLC, CO_2 is the only greenhouse gas produced.
$n(C_8H_{18}) = \frac{m}{M} = \frac{16000}{114.0} = 140.4$ mol $\therefore$ $n(CO_2) = 8 \times 140.4 = 1.12 \times 10^3$ mol
$V(CO_2) = 1.12 \times 10^3 \times 24.8 = 27\,846$ L $= 2.8 \times 10^4$ L to 2 sig. fig. **Correct Answer: D**

Question 3
In an endothermic reaction, the products have a higher enthalpy and weaker bond strength than the reactants. **Correct Answer: B**

Question 4
A−C are exothermic processes. A is cellular respiration and B is incomplete combustion. Both are exothermic. C is condensation. This is an exothermic process. The opposite of this process, evaporation, is endothermic as heat energy is required to break the intermolecular forces. D is sublimation.
Correct Answer: D

Question 5

$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H = -393$ kJ mol^{-1}	$\times 2$	$\Delta H = -726$ kJ mol^{-1}
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$	$\Delta H = -566$ kJ mol^{-1}	*reverse*	$\Delta H = +566$ kJ mol^{-1}
$\therefore 2C(s) + O_2(g) \rightarrow 2CO(g)$	$\Delta H = -726 + 566 = -220$ kJ mol^{-1}		**Correct Answer: B**

Question 6
$CF = \frac{E}{\Delta T}$ $\therefore E = CF \times \Delta T = 480 \times 2.90 = 1392$ J $= 1.39$ kJ
$\Delta H = \frac{E}{n} = \frac{1.39}{0.040} = 34.8 = +35$ kJ mol^{-1} to 2 sig. fig. Temperature decreased hence endothermic.
Correct Answer: D

Question 7
A primary cell when discharging is acting as a galvanic cell, so oxidation occurs at the negatively charged anode. **Correct Answer: B**

Question 8

$Au^+(aq) + e^- \rightleftharpoons Au(s)$	$E^0 = +1.68$ V	
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	$E^0 = +0.68$ V	*(from data book)*

As Half-cell 1 contains the positive electrode, reduction occurs here. As the voltmeter reads 1.00 V, Half-cell 2 must have an E^0 of +0.68 V. Oxidation occurs in Half-cell 2 producing $O_2(g)$ and $H^+(aq)$.
Correct Answer: A

Question 9
The oxidation number for zinc increases from 0 to +2 hence it is oxidised at the anode. In an alkaline cell, the OH^- anions migrate to the anode where they are consumed. **Correct Answer: B**

Question 10
In a hydrogen-oxygen fuel cell, $O_2(g)$ is reduced at the positive cathode. **Correct Answer: A**

Question 11
In a fuel cell, electrons always move from the anode to the cathode and cations (H^+) migrate towards the cathode. **Correct Answer: B**

Question 12
Crushed $CaCO_3$ will have a higher rate of reaction than $CaCO_3$ chips as the fragments are smaller and have a larger surface area. The reaction rate at 45°C will be higher than that at 25°C. It is not D as an increased surface area and temperature have a larger effect on rate than increased concentration of HCl.
Correct Answer: B

Question 13
Catalysts do not increase the yield of a reaction, only the rate. Catalysts do not increase the frequency of collisions. They provide an alternative reaction pathway with a lowered activation energy therefore increasing the proportion of particles with kinetic energy greater than, or equal to, the activation energy barrier. **Correct Answer: D**

Question 14
The reaction is endothermic therefore increased temperature favours the forward reaction hence yield. There are more product particles than reactants hence lowered pressure will favour the forward reaction.
Correct Answer: B

Question 15
If the volume of the container is halved, all initial concentrations double so there will be an equilibrium shift to the right as the reaction that produces the fewest particles will be favoured to decrease the pressure. The amount of NH_3 will increase and the amount of N_2 and H_2 will decrease. However, as the volume is halved, all concentrations will be higher at the new equilibrium. **Correct Answer: D**

Question 16
The reaction is exothermic hence a decrease in temperature will result in an equilibrium shift to the right. The amount of CO will therefore decrease by 0.15 mol. O_2 decreases by half the amount of CO, not double. **Correct Answer: A**

Question 17
A. LiI(aq) would produce $H_2(g)$ at the cathode but $I_2(s)$ at the anode.
B. $CaCl_2$(aq) would produce $H_2(g)$ at the cathode and $O_2(g)$ at the anode. **Correct Answer: B**
C. $NiSO_4$(aq) would produce Ni(s) at the cathode and $O_2(g)$ at the anode.
D. $ZnCl_2$(aq) would produce Zn(s) at the cathode and $O_2(g)$ at the anode

Question 18
CELL A would produce 0.5 mol of Ni(s) at the cathode = 29.4 g
CELL B would produce 0.5 mol Zn(s) at the cathode = 32.7 g **Correct Answer: B**
CELL C would not produce K(s) at the cathode as K^+ is a weaker oxidant than H_2O.

Question 19
A. $AlCl_3$(aq) would not produce Al(s) at the cathode as Al^{3+} is a weaker oxidant than H_2O.
B. $Q = I\,t = 965 \times 100 = 96500$ C = 1.00 mol e^- = 0.500 mol Cu(s).
C. $Q = I\,t = 965 \times 90 = 86850$ C = 0.900 mol e^- = 0.900 mol Ag(s). **Correct Answer: C**
D. $Q = I\,t = 96.5 \times 1000 = 96500$ C = 1.00 mol e^- = 0.333 mol Al(s).

Question 20
Although the *y*-axis has no numerical values, the following can be determined.
1 mol e^- = 1 mol Li = 6.9 g; 1 mol e^- = 1 mol Na = 23.0 g ∴ the mass of the third metal produced from 1 mol e^- is approximately 39 g.
A. 1 mol e^- = 1 mol Ag(s) = 107.9 g
B. 1 mol e^- = 0.5 mol Mg(s) = 12.2 g
C. 1 mol e^- = 1 mol K(s) = 39.1 g **Correct Answer: C**
D. 1 mol e^- = 0.5 mol Ca(s) = 20.0 g

SECTION B (65 marks)

Question 1 (13 marks)

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

ii. Sustainable fuels are able to meet the needs of the current generation and are also able to meet the needs of future generations **(1 mark)**.
Bioethanol is a renewable energy source as the crops that produce the glucose can be replaced by natural processes within a relatively short period of time. Methylated spirits from fossil fuels takes millions of years to replace so the rate of consumption is higher than the rate of production so it is non-renewable **(1 mark)**.
If bioethanol is produced from food crops such as sugarcane, there is the potential for land that would be used for food to instead be used for bioethanol. However, any potential land degradation due to growing crops is less than the environmental damage caused by mining or drilling for fossil fuels **(1 mark)**.
(1 mark for a definition of sustainability; 1 mark for comment on renewability of the two fuels; 1 mark for a comment on damage to the environment or about land use)

b. **i.** $q = mc\Delta T = 1000 \times 4.18 \times (100 - 21.0) = 330\ 220\ J = 330\ kJ$ **(1 mark)**

$n(CH_3CH_2OH) = \frac{25.0}{46.0} = 0.543$ mol **(1 mark)**

Heat of combustion in kJ mol^{-1} $= \frac{\text{energy in kJ}}{\text{mol}} = \frac{330}{0.543} = 608$ kJ mol^{-1} **(1 mark)**

ii. % efficiency $= \frac{\text{experimental heat of combustion}}{\text{theoretical heat of combustion}} \times \frac{100}{1} = \frac{608}{1370} \times \frac{100}{1} = 44.4\%$ **(1 mark)**

(1370 is the heat of combustion from the data book)

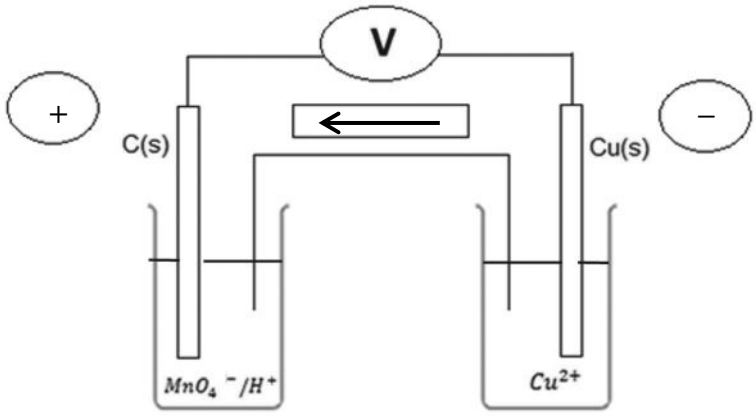
c.
$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ $\Delta H = -1370$ kJ mol^{-1}
$3H_2O(l) \rightarrow 3H_2O(g)$ $\Delta H = (3 \times +40.7) = +122.1$ kJ mol^{-1}
$\therefore CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ $\Delta H = -1248$ kJ mol^{-1}
(1 mark for correctly balanced equation with correct states of matter)
(1 mark for multiplying ΔH for water evaporation by 3)
(1 mark for appropriate value and sign for ΔH in thermochemical equation)

d. For 45 g serving: energy = (4.5 × 17) + (7.4 × 37) + (24.8 × 16) = 747 kJ **(1 mark)**

For 100 g: energy $= 747 \times \frac{100}{45} = 1660 = 1.7 \times 10^3$ kJ / 100 g **(1 mark)**

(17, 37 and 16 are the energy content of proteins, fats and carbohydrates, respectively, as given in the data book)

Question 2 (7 marks)



a. **(1 mark for correct placement of + and – in the circles)**

b. **(1 mark for arrow pointing to the left in the box)**

c. $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ **(1 mark)**

d. **(any two of the following for 1 mark each)**
- purple MnO_4^- solution becomes less purple
- blue Cu^{2+} solution becomes more blue
- Cu electrode / anode / negative electrode appears smaller / corroded / pitted
- Cu electrode / anode / negative electrode loses mass if measured on a weighing balance
- decrease in cell potential difference over time as seen on voltmeter

e. **i.** +0.34 – –0.25 = 0.59 V **(1 mark)** *(E^0 values from the data book)*

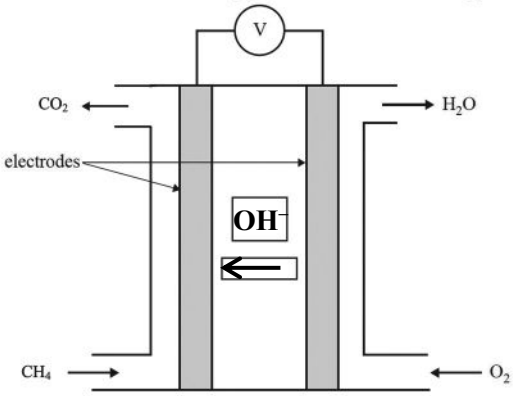
ii. $Cu^{2+}(aq)$ **(1 mark)**

Question 3 (12 marks)

a. $CH_4(g) + 8OH^-(aq) \rightarrow CO_2(g) + 6H_2O(l) + 8e^-$ **(1 mark)**

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

c. chemical energy to electrical energy **(1 mark)**



d. **(1 mark for OH^-)**
(1 mark for arrow to the left)

e. **(any two of the following for 1 mark each)**
- prevents reactants from coming into contact with each other
- surface at which oxidation and reduction take place
- act as a catalyst
- allows electrical conductivity
- allows migration of OH^- ions to reactants

f. $E = V \times Q$ $Q = n(e^-) \times F$

$n(CH_4) = \frac{1000}{16.0} = 62.5$ mol **(1 mark)**

$n(e^-) = 62.5 \times 8 = 500$ mol **(1 mark)**

$Q = 500 \times 96500 = 4.83 \times 10^7$ C

$E = 1.00 \times 4.83 \times 10^7$ J **(1 mark)**

E = 48.3 MJ if 100% efficient **(1 mark)**

$E = 48.3 \times 0.80 = 38.9 = 39$ MJ if 80% efficient **(1 mark for answer to 2 sig. fig.)**

Question 4 (4 marks)

a. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$ **(1 mark)**

b. *The rate of experiment 2 is slower than that of experiment 1. A greater volume of CO_2 is produced in experiment 2 hence a greater n($CaCO_3$) required.*

Larger pieces of $CaCO_3$ (lower surface area) **(1 mark)**
Greater mass of $CaCO_3$ **(1 mark)**

c. Smaller surface area of the larger pieces of $CaCO_3$ means less frequent collisions **(1 mark)** between HCl and $CaCO_3$ hence lower reaction rate.

Question 5 (11 marks)

a.

Change imposed	Observation	Equilibrium shift (left or right)	Effect on K (higher, lower or no effect)	Effect on $[NO_2]$ (higher, lower or no effect)
Increase volume (at constant T)	lighter, then darker	**left**	**no effect**	**lower**
Cool (at constant V)	lighter	**right**	**higher**	**lower**

(1 mark per row)

Explanations: When the volume is increased, the pressure decreases so the reaction that produces more particles is favoured. This is the backward reaction hence equilibrium shift to the left. Only a change in temperature affects K values. Although more NO_2 molecules are produced, the volume has increased hence a lower than original $[NO_2]$.
When the temperature is decreased, the colour went lighter. This indicates a lower $[NO_2]$ hence an equilibrium shift to the right. This increases the K value.

b. When the temperature is decreased, LCP predicts the exothermic reaction will be favoured in order to increase the temperature **(1 mark)**. As the forward reaction was favoured, the forward reaction is exothermic ∴ the sign for the ΔH is negative **(1 mark)**.

c. $K = \frac{[N_2O_4]}{[NO_2]^2}$ **(1 mark)**

d. $[NO_2]^2 = \frac{[N_2O_4]}{K} = \frac{1.85}{216} = 0.00856$ M **(1 mark)**

∴ $[NO_2] = \sqrt{0.00856} = 0.0925$ M **(1 mark)**

e. $[NO_2] = \frac{0.175}{2.50} = 0.0700$ M $\quad [N_2O_4] = \frac{0.320}{2.50} = 0.128$ M **(1 mark)**

$Q = \frac{[N_2O_4]}{[NO_2]^2} = \frac{0.128}{0.0700^2} = 26.1\ M^{-1}$ $\quad Q < K$ i.e. $26.1 < 216$ **(1 mark)**

Equilibrium will be achieved via a net forward reaction **(1 mark)** in order to increase Q.

f. *The reaction coefficients have been halved and the reaction has been reversed.*
$\therefore K = \frac{1}{\sqrt{216}} = 0.0680\ M^{1/2}$ **(1 mark for correct value of K with correct unit)**

Question 6 (7 marks)

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

ii. $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ **(1 mark)**

b. **i.** $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ **(1 mark)**

ii. $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ **(1 mark)**

c. **i.** graphite / Pt / C(s) **(1 mark)**

ii. Ni(s) **(1 mark)**

d. *Electrode A was positive in Variation 1 as oxidation occurred there and negative in Variation 2 as reduction occurred there.*
Explanation: A gas that was not $Cl_2(g)$ was produced at Electrode A in Variation 1 so it could have been $O_2(g)$ due to oxidation of H_2O, or $H_2(g)$ due to reduction of H_2O. However, a coating appeared in Electrode B in Variation 1 which could only be Ni(s) due to reduction of Ni^{2+} ions. Hence oxidation of H_2O occurred at Electrode A in Variation 1.

The polarities of the electrodes A and B were reversed **(1 mark)**

Question 7 (11 marks)

a. **i.** $2Br^-(aq) \rightarrow Br_2(aq) + 2e^-$ **(1 mark)**

ii. $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ **(1 mark)**

b. To keep the reactants of discharge or products of recharge (Zn(s) and $Br_2(aq)$) separate from each other **(1 mark)**.

c. **i.** carbon **(1 mark)**

ii. zinc / Zn **(1 mark)**

d.

During **discharge**, the Zn^{2+} ions migrate to the:	positive electrode ✓	negative electrode
During **recharge**, the Br^- ions migrate to the:	positive electrode ✓	negative electrode

(1 mark per tick)

e. $n(Zn) = \frac{125}{65.4} = 1.91$ mol $\therefore n(e^-) = 2 \times n(Zn) = 3.82$ mol **(1 mark)**
$Q = n(e^-) \times F = 3.82 \times 96500 = 3.69 \times 10^5$ C **(1 mark)**
$t = \frac{Q}{I} = \frac{3.69 \times 10^5}{4.50} = 8.20 \times 10^4$ s **(1 mark)** = 22.8 hours **(1 mark)**

END OF SUGGESTED SOLUTIONS