SCIENCE TEACHERS ASSOCIATION VICTORIA 2023

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.

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

Comments for Section A answers.

Question 1
No discussion required. **Correct Answer: B**

Question 2
Using energy/mass ratios: $\frac{1300 \text{ kJ}}{26 \text{ g}} = \frac{x}{0.52}$ $x = \frac{1300 \times 0.52}{26}$ = 26 kJ released

Correct Answer: D

Question 3
$n(C_2H_2) = \frac{m}{M} = \frac{0.52}{26} = 0.020$ mol
From the equation, $n(CO_2) = 2 \times n(C_2H_2) = 0.040$ mol
$m(CO_2) = n \times M = 0.040 \times 44.0$ g = 1.76 g
1.76 g for 26 kJ = 1.00 g for 14.8 kJ = 1000 g for 14.8 MJ
$\frac{1000}{14.8}$ = 67.7 g for 1 MJ **Correct Answer: B**

Question 4
$E = mc\Delta T = 150 \times 4.18 \times 60.0 = 37620$ J = 37.62 kJ
E per gram = $\frac{37.62}{9.00} = 4.18$ kJ g^{-1} **Correct Answer: C**

Question 5
Batteries are very efficient in converting energy. **Correct Answer: D**

Question 6
In an endothermic reaction, total energy increases but the bonds will be weaker.

Correct Answer: B

Question 7
An oxidising agent causes oxidation but itself is reduced. The only increase in oxidation number is for Cl^- (Cl = −1) to ClO^- (Cl = +1) **Correct Answer: C**

Question 8
Higher pressure means a faster rate of reaction and if P↑, LCP would require a shift to the side with less particles to ↓P, i.e. more SO_3. This leads to a higher equilibrium yield.

Correct Answer: A

Question 9
$[C_2H_6] = 2 \times 1.25 \times 10^{-1} = 0.250$ M $[C_2H_4] = 2 \times 7.50 \times 10^{-2} = 0.150$ M
$[H_2] = 2 \times 8.35 \times 10^{-2} = 0.167$ M
$K = \frac{[C_2H_6]}{[C_2H_4] \times [H_2]} = \frac{0.250}{0.150 \times 0.167} = 9.98 \text{ M}^{-1}$ **Correct Answer: C**

Question 10
Only temperature can change the equilibrium constant. **Correct Answer: D**

Question 11

	I_2	I^-	I_3^-
n_i	0.010	0.20	–
n_r	0.0099	0.0099	–
n_{eq}	0.0001	0.1901	0.0099
$[\ ]_{eq}$	0.0001	0.1901	0.0099

$$K = \frac{[I_3^-]}{[I^-] \times [I_2]} = \frac{0.0099}{0.1901 \times 0.0001}$$

$K = 521\ M^{-1}$ **Correct Answer: A**

Question 12

$K = \frac{[H_2][I_2]}{[HI]^2}$ $\quad 0.040 = \frac{x^2}{0.20^2}$ $\quad x = \sqrt{0.0016} = 0.040$ **Correct Answer: B**

Question 13
The new equation is the reverse of the original and with half the coefficients.
Therefore $K^{|} = \frac{1}{\sqrt{K}} = \frac{1}{\sqrt{7.34 \times 10^{34}}}$ **Correct Answer: B**

Question 14
For a spontaneous reaction, the oxidising agent has to be higher placed in the ES (provided in the data book) than the reducing agent. This is only true for Zn and Ag^+. **Correct Answer: B**

Question 15
$E = E^o(+) – E^o(−)$
$E = E^o(Pb) – E^o(Ni) = −0.13 – (−0.25) = +0.12$ V **Correct Answer: A**

Question 16
The last alternative is balanced for atoms and charge and has the correct product of I_2.
Correct Answer: D

Question 17
For spontaneous reaction, the oxidising agent has to be higher placed in the ES than the reducing agent. See data below. Only IO_3^- will oxidise Br^-. **Correct Answer: A**

$2IO_3^- + 12H^+ + 10e^- \rightleftharpoons I_2 + 6H_2O$ $\quad E^o = +1.19$ V

$Br_2 + 2e^- \rightleftharpoons 2Br^-$ $\quad E^o = +1.09$ V

$Cu^{2+} + 2e^- \rightleftharpoons Cu$ $\quad E^o = +0.34$ V

$V^{3+} + e^- \rightleftharpoons V^{2+}$ $\quad E^o = −0.26$ V

$2H^+ + 2e^- \rightleftharpoons H_2$ $\quad E^o = 0.00$ V

Question 18
In an oxygen / methanol fuel cell, the methanol is the fuel and is oxidised (the reducing agent) at the anode. **Correct Answer: C**

Question 19
$CuBr_2$ would produce Cu and Br_2 in the molten cell. In aqueous solution, the same products are formed as Cu^{2+} is a stronger oxidising agent than H_2O and Br^- is a stronger reducing agent than water. **Correct Answer: D**

Question 20

n(Cu) = $\frac{m}{M} = \frac{1.0}{63.5}$ = 0.01575 mol n(Ag) = 2 × n(Cu) = 0.0315 mol

m(Ag) = n × M = 0.0315 × 107.9 = 3.40 g **Correct Answer: D**

Section B (73 marks)

Question 1 (7 marks)

a. **0** **−1** **+1** **(oxidation numbers of Cl)**

$Cl_2(aq) + 2OH^-(aq) \rightleftharpoons Cl^-(aq) + ClO^-(aq) + H_2O(l)$

The oxidation number of chlorine has both increased and decreased as shown above.

$Cl_2(aq) \rightarrow Cl^-$ reduction (decrease in oxidation number of chlorine from 0 to −1) **(1 mark)**

$Cl_2(aq) \rightarrow ClO^-$ oxidation (increase in oxidation number of chlorine from 0 to +1) **(1 mark)**

Therefore it is a redox reaction.

b. The reducing agent is oxidised **(1 mark)**. Cl^- is oxidised to Cl_2 **(1 mark)**.

c. $[Cl_2]\uparrow$, according to LCP, the system will partially offset the increase with net forward reaction **(1 mark)**. This will decrease the $[OH^-]$ **(1 mark)** and the pH will therefore decrease **(1 mark)**.

Question 2 (13 marks)

a. m(butan-1-ol) = d × V = 0.81 × 20.0 = 16.2 g **(1 mark)** M(butan-1-ol) = 74.0 g mol^{-1}

5 × 18.0 g of water is produced from 74.0 g **(1 mark)**

using ratio: $\frac{90.0}{74.0} = \frac{x}{16.2}$ x = 19.7 g = 20 g (2sf) of water **(1 mark)**

b. From the equation there is 4 mol of CO_2 per 1 mol of butan-1-ol **(1 mark)**

$n(CO_2) = 4 \times \frac{16.2}{74.0}$ = 0.8757 mol **(1 mark)**

$n = \frac{V}{V_M}$ $V(CO_2)$ = 0.8757 × 24.8 = 21.7 L = 22 L (2sf) **(1 mark)**

c. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $\frac{0.987 \times 21.7}{298} = \frac{1.60 \times V_2}{373}$ **(1 mark)**

$V_2 = \frac{0.987 \times 21.7 \times 373}{298 \times 1.60}$ = 16.8 L = 17 L (2sf) **(1 mark)**

d. $n(CO_2) = \frac{V}{V_M} = \frac{0.100}{24.8}$ = 0.00403 mol **(1 mark)**

n(butan-1-ol) = ¼ × 0.00403 = 0.00101 mol **(1 mark)**

m(butan-1-ol) = n × M = 0.00101 × 74.0 = 0.0746 g **(1 mark)**

e. 1 mol butan-1-ol produces 2670 kJ and 1 mol ethanol produces 1360 kJ (from data book)

n(ethanol) = $\frac{2670}{1360}$ = 1.963 mol **(1 mark)**

m(ethanol) = n × M = 1.963 × 46.0 = 90.3 g **(1 mark)**

Question 3 (8 marks)

a. E = mcΔT E = 0.100 × 875 × 80.0 = 7000 J = 7.00 kJ
(**1 mark** for conversion of units to kg and **1 mark** for correct value)

b. Total energy = 7.00 + $\frac{500 \times 4.18 \times 80.0}{1000}$ (**1 mark**)
= 7.00 + 167.2 = 174 kJ (**1 mark**)

c. n(butane) = $\frac{m}{M} = \frac{7.25}{58.0}$ = 0.125 mol (**1 mark**)

d. using ratio of energy : mol $\frac{174}{0.125} = \frac{x}{1.00}$ (**1 mark**)
$x = 1.39 \times 10^3$ kJ mol^{-1} released (**1 mark**)

e. A large amount of heat is lost to the atmosphere (**1 mark**)

Question 4 (5 marks)

a. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ ΔH = −2816 kJ mol^{-1}
(**1 mark** for correctly balanced equation and **1 mark** for correct value of ΔH)
(**1 mark** for correct states (glucose must be solid) & **1 mark** for correct ΔH sign & unit)

b. M(glucose) = 180 g mol^{-1} energy per gram = $\frac{2816}{180.0}$ = 15.64 kJ g^{-1} (**1 mark**)

Question 5 (9 marks)

a. The reaction is exothermic in the forward direction as the ΔH is negative **(1 mark)**.

b. As the reaction proceeds, energy is released to the environment **(1 mark)** and so the products are lower in energy meaning the reactants have the greater enthalpy **(1 mark)**.

c. The reaction is the reverse of the given equation with half co-efficients.
½ × 576 = +288 kJ mol^{-1} **(1 mark)**

d. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ ΔH = −576 kJ mol^{-1}
$2H_2O(l) \rightarrow 2H_2O(g)$ ΔH = +88 kJ mol^{-1} **(1 mark)**

adding the two equations gives:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ **(1 mark)** ΔH = −488 kJ mol^{-1} **(1 mark)**

e. In the fuel cell the electrode must be porous and catalytic. Being porous allows the gases at each electrode to make contact with the electrolyte to allow current to flow **(1 mark)**. Being catalytic allows a much lower activation energy **(1 mark)** and therefore a lower resistance and higher current.

Question 6 (10 marks)

a. $K_c = \frac{[COCl_2]}{[CO] \times [Cl_2]}$ **(1 mark)**

b. $K_c = \frac{0.200}{0.800 \times 0.600} = 0.417$ **(1 mark)** M^{-1} **(1 mark)**

c. **i.** If V is halved, P doubles.
If the pressure doubles, according to LCP, the system will try to partially counteract this by moving to the side which has less molecules to reduce pressure **(1 mark)** i.e. more $COCl_2$ will be produced **(1 mark)**.

ii. CF (concentration fraction) = $\frac{0.400}{1.60 \times 1.20} = 0.208\ M^{-1}$ **(1 mark)**

System is not at equilibrium **(1 mark)**
The CF must increase to restore equilibrium **(1 mark)**
Therefore, a net forward reaction occurs to increase the CF **(1 mark)** until once again it is equal to $0.417\ M^{-1}$

d. Yes, this is consistent with the prediction in **part ci**., that more $COCl_2$ is produced **(1 mark)**

Question 7 (5 marks)

At equilibrium, $n(A)_{eq} = 5.0 - 1.0 = 4.0$ mol $[A]_{eq} = \frac{n}{V} = \frac{4.0}{2.0} = 2.0$ M **(1 mark)**

At equilibrium, $n(B)_{eq} = 2.0 - 1.0 = 1.0$ mol $[B]_{eq} = \frac{n}{V} = \frac{1.0}{2.0} = 0.50$ M **(1 mark)**

At equilibrium, $n(C)_{eq} = 3.0$ mol $[C]_{eq} = \frac{n}{V} = \frac{3.0}{2.0} = 1.5$ M **(1 mark)**

$K = \frac{[C]^3}{[A] \times [B]}$ **(1 mark)** $K = \frac{1.5^3}{2.0 \times 0.50} = 3.4$ M **(1 mark)**

Question 8 (5 marks)

a. The strongest oxidising agent will be reduced and the strongest reducing agent will be oxidised **(1 mark)**. The two half-cells are placed in their correct order as shown below:

$$Y^{2+} + 2e^- \rightarrow Y \qquad E^o = +0.87\ V$$

$$X^{2+} + 2e^- \rightarrow X \qquad E^o = +0.45\ V$$

In the galvanic cell, Y^{2+} will be reduced and X will be oxidised **(1 mark)**.
<u>Metal Y</u> is the cathode which is positive in a galvanic cell **(1 mark)**.

b. No **(1 mark)**. If Y was to still protect X , Y must be a stronger reducing agent **(1 mark)**.

Question 9 (5 marks)

When the two different metals sitting in a solution containing ions are in contact, 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)**

The electrons are then accepted by 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 or $Ni(s) + 2H^{+}(aq) \rightarrow Ni^{2+}(aq) + H_2(g)$ **(1 mark)**

The Cu cannot react with the H^+ ions under these conditions as it is a weaker reductant than H_2 **(1 mark)**

Question 10 (6 marks)

$n(Cl_2) = \frac{V}{V_M} = \frac{2.1}{24.8} = 0.08468$ mol **(1 mark)**

$n(e^-) = 2 \times n(Cl_2) = 0.1694$ mol **(1 mark)**

$Q = n(e^-) \times F = 0.1694 \times 96500 = 16\,343$ C **(1 mark)**

$t = \frac{Q}{I} = \frac{16\,343}{7.50} = 2179$ s **(1 mark)**

$t = \frac{2179}{60} = 36$ mins **(1 mark)** 2 sf **(1 mark)**

END OF SUGGESTED SOLUTIONS