

# CHEMISTRY

## UNIT 3



Published by STAV  
© STAV March 2023

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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
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**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:  $\frac{1300 \text{ kJ}}{26 \text{ g}} = \frac{x}{0.52}$        $x = \frac{1300 \times 0.52}{26} = 26 \text{ kJ released}$

**Correct Answer: D****Question 3**

$$n(\text{C}_2\text{H}_2) = \frac{m}{M} = \frac{0.52}{26} = 0.020 \text{ mol}$$

From the equation,  $n(\text{CO}_2) = 2 \times n(\text{C}_2\text{H}_2) = 0.040 \text{ mol}$

$$m(\text{CO}_2) = n \times M = 0.040 \times 44.0 \text{ g} = 1.76 \text{ g}$$

1.76 g for 26 kJ = 1.00 g for 14.8 kJ = 1000 g for 14.8 MJ

$$\frac{1000}{14.8} = 67.7 \text{ g for 1 MJ} \quad \text{Correct Answer: B}$$

**Question 4**

$$E = mc\Delta T = 150 \times 4.18 \times 60.0 = 37620 \text{ J} = 37.62 \text{ kJ}$$

$$E \text{ per gram} = \frac{37.62}{9.00} = 4.18 \text{ kJ g}^{-1} \quad \text{Correct Answer: C}$$

**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  $\text{Cl}^-$  ( $\text{Cl} = -1$ ) to  $\text{ClO}^-$  ( $\text{Cl} = +1$ ) **Correct Answer: C**

**Question 8**

Higher pressure means a faster rate of reaction and if  $P \uparrow$ , LCP would require a shift to the side with less particles to  $\downarrow P$ , i.e. more  $\text{SO}_3$ . This leads to a higher equilibrium yield.

**Correct Answer: A****Question 9**

$$[\text{C}_2\text{H}_6] = 2 \times 1.25 \times 10^{-1} = 0.250 \text{ M} \quad [\text{C}_2\text{H}_4] = 2 \times 7.50 \times 10^{-2} = 0.150 \text{ M}$$

$$[\text{H}_2] = 2 \times 8.35 \times 10^{-2} = 0.167 \text{ M}$$

$$K = \frac{[\text{C}_2\text{H}_6]}{[\text{C}_2\text{H}_4] \times [\text{H}_2]} = \frac{0.250}{0.150 \times 0.167} = 9.98 \text{ M}^{-1} \quad \text{Correct Answer: C}$$

**Question 10**

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

**Question 11**

	$I_2$	$I^-$	$I_3^-$	$K = \frac{[I_3^-]}{[I^-] \times [I_2]} = \frac{0.0099}{0.1901 \times 0.0001}$
$n_i$	0.010	0.20	–	
$n_r$	0.0099	0.0099	–	$K = 521 \text{ M}^{-1}$ <b>Correct Answer: A</b>
$n_{eq}$	0.0001	0.1901	0.0099	
$[ ]_{eq}$	0.0001	0.1901	0.0099	

**Question 12**

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

**Question 13**

The new equation is the reverse of the original and with half the coefficients.

$$\text{Therefore } K^1 = \frac{1}{\sqrt{K}} = \frac{1}{\sqrt{7.34 \times 10^{34}}} \quad \text{Correct Answer: B}$$

**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**

$$E = E^{\circ}(+) - E^{\circ}(-)$$

$$E = E^{\circ}(Pb) - E^{\circ}(Ni) = -0.13 - (-0.25) = +0.12 \text{ V} \quad \text{Correct Answer: A}$$

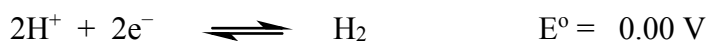
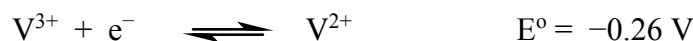
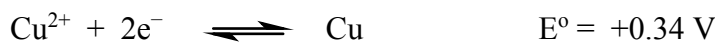
**Question 16**

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**

**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**

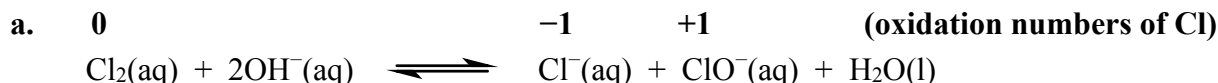
**Question 19**

$CuBr_2$  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**

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

$$m(\text{Ag}) = n \times M = 0.0315 \times 107.9 = 3.40 \text{ g} \quad \text{Correct Answer: D}$$

**Section B (73 marks)****Question 1 (7 marks)**

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

$\text{Cl}_2(\text{aq}) \rightarrow \text{Cl}^-$  reduction (decrease in oxidation number of chlorine from 0 to -1) **(1 mark)**

$\text{Cl}_2(\text{aq}) \rightarrow \text{ClO}^-$  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)**.  $\text{Cl}^-$  is oxidised to  $\text{Cl}_2$  **(1 mark)**.

c.  $[\text{Cl}_2] \uparrow$ , according to LCP, the system will partially offset the increase with net forward reaction **(1 mark)**. This will decrease the  $[\text{OH}^-]$  **(1 mark)** and the pH will therefore decrease **(1 mark)**.

**Question 2 (13 marks)**

a.  $m(\text{butan-1-ol}) = d \times V = 0.81 \times 20.0 = 16.2 \text{ g}$  **(1 mark)**  $M(\text{butan-1-ol}) = 74.0 \text{ g mol}^{-1}$   
 $5 \times 18.0 \text{ g}$  of water is produced from  $74.0 \text{ g}$  **(1 mark)**

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

b. From the equation there is 4 mol of  $\text{CO}_2$  per 1 mol of butan-1-ol **(1 mark)**

$$n(\text{CO}_2) = 4 \times \frac{16.2}{74.0} = 0.8757 \text{ mol} \text{ (1 mark)}$$

$$n = \frac{V}{V_M} \quad V(\text{CO}_2) = 0.8757 \times 24.8 = 21.7 \text{ L} = 22 \text{ L} \text{ (2sf) (1 mark)}$$

c.  $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \frac{0.987 \times 21.7}{298} = \frac{1.60 \times V_2}{373}$  **(1 mark)**

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

d.  $n(\text{CO}_2) = \frac{V}{V_M} = \frac{0.100}{24.8} = 0.00403 \text{ mol}$  **(1 mark)**

$$n(\text{butan-1-ol}) = \frac{1}{4} \times 0.00403 = 0.00101 \text{ mol} \text{ (1 mark)}$$

$$m(\text{butan-1-ol}) = n \times M = 0.00101 \times 74.0 = 0.0746 \text{ g} \text{ (1 mark)}$$

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

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

$$m(\text{ethanol}) = n \times M = 1.963 \times 46.0 = 90.3 \text{ g} \text{ (1 mark)}$$

**Question 3 (8 marks)**

- a.  $E = mc\Delta T$      $E = 0.100 \times 875 \times 80.0 = 7000 \text{ J} = 7.00 \text{ kJ}$   
(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)  
 $= 7.00 + 167.2 = 174 \text{ kJ}$  (1 mark)
- c.  $n(\text{butane}) = \frac{m}{M} = \frac{7.25}{58.0} = 0.125 \text{ mol}$  (1 mark)
- d. using ratio of energy : mol     $\frac{174}{0.125} = \frac{x}{1.00}$  (1 mark)  
 $x = 1.39 \times 10^3 \text{ kJ mol}^{-1}$  released (1 mark)
- e. A large amount of heat is lost to the atmosphere (1 mark)

**Question 4 (5 marks)**

- a.  $\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l})$      $\Delta H = -2816 \text{ kJ mol}^{-1}$   
(1 mark for correctly balanced equation and 1 mark for correct value of  $\Delta H$ )  
(1 mark for correct states (glucose must be solid) & 1 mark for correct  $\Delta H$  sign & unit)
- b.  $M(\text{glucose}) = 180 \text{ g mol}^{-1}$     energy per gram =  $\frac{2816}{180.0} = 15.64 \text{ kJ g}^{-1}$  (1 mark)

**Question 5 (9 marks)**

- a. The reaction is exothermic in the forward direction as the  $\Delta H$  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.  
 $\frac{1}{2} \times 576 = +288 \text{ kJ mol}^{-1}$  (1 mark)
- d.  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$      $\Delta H = -576 \text{ kJ mol}^{-1}$   
 $2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2\text{O}(\text{g})$      $\Delta H = +88 \text{ kJ mol}^{-1}$  (1 mark)  
adding the two equations gives:  
 $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$  (1 mark)     $\Delta H = -488 \text{ kJ mol}^{-1}$  (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.  $K_c = \frac{[\text{COCl}_2]}{[\text{CO}] \times [\text{Cl}_2]} \quad (1 \text{ mark})$

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

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  $\text{COCl}_2$  will be produced **(1 mark)**.

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

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  $0.417 \text{ M}^{-1}$

d. Yes, this is consistent with the prediction in **part ci.**, that more  $\text{COCl}_2$  is produced **(1 mark)**

**Question 7 (5 marks)**

At equilibrium,  $n(\text{A})_{\text{eq}} = 5.0 - 1.0 = 4.0 \text{ mol}$

$$[\text{A}]_{\text{eq}} = \frac{n}{V} = \frac{4.0}{2.0} = 2.0 \text{ M} \quad (1 \text{ mark})$$

At equilibrium,  $n(\text{B})_{\text{eq}} = 2.0 - 1.0 = 1.0 \text{ mol}$

$$[\text{B}]_{\text{eq}} = \frac{n}{V} = \frac{1.0}{2.0} = 0.50 \text{ M} \quad (1 \text{ mark})$$

At equilibrium,  $n(\text{C})_{\text{eq}} = 3.0 \text{ mol}$

$$[\text{C}]_{\text{eq}} = \frac{n}{V} = \frac{3.0}{2.0} = 1.5 \text{ M} \quad (1 \text{ mark})$$

$$K = \frac{[\text{C}]^3}{[\text{A}] \times [\text{B}]} \quad (1 \text{ mark})$$

$$K = \frac{1.5^3}{2.0 \times 0.50} = 3.4 \text{ M} \quad (1 \text{ mark})$$

**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:



In the galvanic cell,  $\text{Y}^{2+}$  will be reduced and X will be oxidised **(1 mark)**.

Metal Y is the cathode which is positive in a galvanic cell **(1 mark)**.

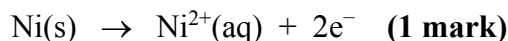
b. No **(1 mark)**. If Y was to still protect X, Y must be a stronger reducing agent **(1 mark)**.

**Question 9 (5 marks)**

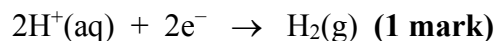
When the two different metals sitting in a solution containing ions are in contact, a galvanic cell is set up and the more reactive metal, Ni, passes electrons on to the less reactive metal, Cu.

**(1 mark)**

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



The electrons are then accepted by  $\text{H}^{+}$  ions at the surface of the copper causing  $\text{H}_2$  to form.



When the two metals are not connected, but just sit in the acid, nickel will react with the  $\text{H}^{+}$  ions at the surface of the nickel causing  $\text{H}_2$  to form or  $\text{Ni(s)} + 2\text{H}^{+}(\text{aq}) \rightarrow \text{Ni}^{2+}(\text{aq}) + \text{H}_2(\text{g})$

**(1 mark)**

The Cu cannot react with the  $\text{H}^{+}$  ions under these conditions as it is a weaker reductant than  $\text{H}_2$

**(1 mark)**

**Question 10 (6 marks)**

$$n(\text{Cl}_2) = \frac{V}{V_M} = \frac{2.1}{24.8} = 0.08468 \text{ mol} \quad \text{(1 mark)}$$

$$n(\text{e}^{-}) = 2 \times n(\text{Cl}_2) = 0.1694 \text{ mol} \quad \text{(1 mark)}$$

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

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

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

**END OF SUGGESTED SOLUTIONS**