

Name of the Student: _____

Max. Marks : 16 Marks

Time : 16 Minutes

Mark Schemes

Q1.

- (a) Bonds broken = $2(\text{C}=\text{O}) + 3(\text{H}-\text{H}) = 2 \times 743 + 3 \times \text{H}-\text{H}$
 Bonds formed = $3(\text{C}-\text{H}) + (\text{C}-\text{O}) + 3(\text{O}-\text{H}) = 3 \times 412 + 360 + 3 \times 463$
Both required 1
- $-49 = [2 \times 743 + 3 \times (\text{H}-\text{H})] - [3 \times 412 + 360 + 3 \times 463]$
 $3(\text{H}-\text{H}) = -49 - 2 \times 743 + [3 \times 412 + 360 + 3 \times 463] = 1450$
Both required 1
- $\text{H}-\text{H} = 483 \text{ (kJ mol}^{-1}\text{)}$
Allow 483.3(3) 1
- (b) Mean bond enthalpies are not the same as the actual bond enthalpies in CO_2 (and / or methanol and / or water) 1
- (c) The carbon dioxide (produced on burning methanol) is used up in this reaction 1
- (d) 4 mol of gas form 2 mol 1
- At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure 1
- This increases the yield of methanol 1
- (e) Impurities (or sulfur compounds) block the active sites
Allow catalyst poisoned 1
- (f) Stage 1: moles of components in the equilibrium mixture
Extended response question
- $\text{CO}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g}) + \text{H}_2\text{O}(\text{g})$
- | | | | | |
|---------|-----|-----|---|---|
| Initial | 1.0 | 3.0 | 0 | 0 |
|---------|-----|-----|---|---|

moles

Eqm moles	$(1-0.86)$ $= 0.14$	$(3-3 \times 0.86)$ $= 0.42$	0.86	0.86
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1

Stage 2: Partial pressure calculations

Total moles of gas = 2.28

Partial pressures = mol fraction $\times$ p_{total}

1

$$p_{\text{CO}_2} = \text{mol fraction} \times p_{\text{total}} = 0.14 \times 500 / 2.28 = 30.7 \text{ kPa}$$

$$p_{\text{H}_2} = \text{mol fraction} \times p_{\text{total}} = 0.42 \times 500 / 2.28 = 92.1 \text{ kPa}$$

M3 is for partial pressures of both reactants

Alternative M3 =

$$pp_{\text{CO}_2} = 0.0614 \times 500$$

$$pp_{\text{H}_2} = 0.1842 \times 500$$

1

$$p_{\text{CH}_3\text{OH}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500 / 2.28 = 188.6 \text{ kPa}$$

$$p_{\text{H}_2\text{O}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500 / 2.28 = 188.6 \text{ kPa}$$

M4 is for partial pressures of both products

Alternative M4 =

$$pp_{\text{CH}_3\text{OH}} = 0.3772 \times 500$$

$$pp_{\text{H}_2\text{O}} = 0.3772 \times 500$$

1

Stage 3: Equilibrium constant calculation

$$K_p = p_{\text{CH}_3\text{OH}} \times p_{\text{H}_2\text{O}} / p_{\text{CO}_2} \times (p_{\text{H}_2})^3$$

1

$$\text{Hence } K_p = 188.6 \times 188.6 / 30.7 \times (92.1)^3 = 1.483 \times 10^{-3} = 1.5 \times 10^{-3}$$

Answer must be to 2 significant figures

1

$$\text{Units} = \underline{\text{kPa}}^{-2}$$

1

[16]