



Dr Clays A-level Chemistry

# Kc and Kp Past Paper ANSWERS



## Kc &amp; Kp Past Pape ANSWERS

**M1.(a)** Stage 1: Moles of acid at equilibrium

$$\begin{aligned} \text{Moles of sodium hydroxide in each titration} \\ = (3.20 \times 2.00 \times 10^{-1}) / 1000 = 6.40 \times 10^{-4} \end{aligned}$$

*Extended response*

1

$$\begin{aligned} \text{Sample} = 10 \text{ cm}^3 \text{ so moles of acid in } 250 \text{ cm}^3 \text{ of equilibrium mixture} \\ = 25 \times 6.40 \times 10^{-4} = 1.60 \times 10^{-2} \end{aligned}$$

*M2 can only be scored if = answer to M1  $\times$  25*

1

Stage 2: Moles of ester and water formed

$$\text{Moles of acid reacted} = 8.00 \times 10^{-2} - 1.60 \times 10^{-2} = 6.40 \times 10^{-2}$$

= moles ester and water formed

*M3 is  $8.00 \times 10^{-2} - M2$*

1

Stage 3: Moles of ethanol at equilibrium

$$\text{Moles of ethanol remaining} = 1.20 \times 10^{-1} - 6.40 \times 10^{-2} = 5.60 \times 10^{-2}$$

*M4 is  $1.20 \times 10^{-1} - M3$*

1

Stage 4: Calculation of equilibrium constant

$$K_c = [\text{CH}_3\text{COOCH}_2\text{CH}_3] [\text{H}_2\text{O}] / [\text{CH}_3\text{COOH}] [\text{CH}_3\text{CH}_2\text{OH}]$$

1

$$= (6.40 \times 10^{-2})^2 / (1.60 \times 10^{-2})(5.60 \times 10^{-2})$$

$$= 4.5714 = 4.57$$

*M6 is  $M3^2 / M2 \times M4$*

*Answer must be given to 3 significant figures*

1

(b)

Rough	1	2	3
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<b>Final burette reading / cm<sup>3</sup></b>	4.60	8.65	12.85	16.80
<b>Initial burette reading / cm<sup>3</sup></b>	0.10	4.65	8.65	12.85
<b>Titre / cm<sup>3</sup></b>	4.50	4.00	4.20	3.95

1

- (c) Mean =  $4.00 + 3.95 / 2 = 3.98$  (cm<sup>3</sup>)  
*Allow 3.975 (cm<sup>3</sup>)*

1

Titres 1 and 3 are concordant  
*Allow titre 2 is not concordant*

1

- (d) Thymol blue

1

- (e) Percentage uncertainty:  $0.15 / 3.98 \times 100 = 3.77\%$   
*Allow consequential marking on mean titre from 2.3*

1

- (f) Use a lower concentration of NaOH

1

So that a larger titre is required (reduces percentage uncertainty in titre)

1

**[13]**

- M2.(a)** amount of X =  $0.50 - 0.20 = 0.30$  (mol)

1

amount of Y =  $0.50 - 2 \times 0.20 = 0.10$  (mol)



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1

- (b) Axes labelled with values, units and scales that use over half of each axis

*All three of values, units and scales are required for the mark*

1

Curve starts at origin

1

Then flattens at 30 seconds at 0.20 mol

1

- (c) Expression =  $K_c = \frac{[Z]}{[X][Y]^2}$

1

$$[Y]^2 = \frac{[Z]}{[X] K_c}$$

1

$$[Y] = (0.35 / 0.40 \times 2.9)^{0.5} = 0.5493 = 0.55 \text{ (mol dm}^{-3}\text{)}$$

*Answer must be to 2 significant figures*

1

- (d) Darkened / went more orange

1

The equilibrium moved to the right

1

To oppose the increased concentration of Y

1



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(e) The orange colour would fade

1  
[12]

$$\text{M3.(a)} \quad K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$$

Penalise ( ) in this part but can score units; mark on in (b)

If  $K_c$  expression wrong no marks in this part but can score M1 & M3 in (b)

1

units = mol<sup>-1</sup> dm<sup>3</sup>

1

$$\text{(b)} \quad [\text{O}_2] = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 K_c} \text{ or } \frac{(0.072/1.4)^2}{(0.055/1.4)^2 \times 27.9} \text{ or } \frac{(0.072)^2}{(0.055)^2 \times 27.9}$$

Correct answer scores three marks

Ignore ( ) in this part

Penalise contradiction in M1

M1

1

0.061(4)

If  $K_c$  expression wrong in (a) can score M1 here for rearrangement of their  $K_c$  & M3 for multiplication by 1.4

M2

mol O<sub>2</sub> = 0.0614 × 1.4 = 0.086 (allow 0.085–0.087)

If  $K_c$  or rearrangement wrong here score only M3 for multiplication by 1.4

1

M3 = correct answer of (M2 × 1.4)

M3

1



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(c) (i) No effect **OR** none **OR** no change **OR** stays the same 1

(ii) Effect: Increase or more SO<sub>3</sub>

Increase or more SO<sub>3</sub>

*If wrong effect, no further marks, but M2 and M3 are independent of each other*

M1

1

Fewer mole(cule)s on RHS

or 3 moles to 2 moles

or (eqm shifts) to side with fewer moles

(V<sup>3</sup> or) residual V decreases in numerator of K<sub>c</sub> expression

M2

1

Equilibrium moves / shifts to reduce the pressure /  
oppose the increase in pressure

to keep K<sub>c</sub> constant,

$$\text{ratio } \frac{(\text{mol SO}_3)^2}{(\text{mol SO}_2)^2(\text{mol O}_2)}$$

must increase

*Allow to oppose the change only if increase pressure mentioned*

M3

1

[9]

**M4.(a)** (i) Award mark for **X on the time axis** at the point where the lines just become **horizontal**

*Allow this mark if X is above the letters "sh" in the word "show" in part(ii) - in the range of lines 31 to 33.*

1

(ii) They are equal / the same



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OR

Forward (rate) = Reverse / backward (rate)  
*Allow the word 'speed' in this context.  
Ignore reference to concentration.*

1

(b) Both **OR** forward and reverse reactions occur at the same time

**OR** both are occurring at once

**OR** both occur all of the time

**OR** both are ongoing

**OR** both never stop

*Ignore 'at equal rates'.*

*Ignore reference to concentration or equilibrium.*

*The idea that both reactions occur simultaneously is essential.*

*The simple idea of 'both reactions occurring' is insufficient for the mark.*

1

(c) (i) **M1** No effect / no change / none / stays the same

**M2** requires correct **M1**

*In **M2**, ignore reference to particles or atoms.*

**M2** Equal (number of) moles / molecules on both sides

2

(ii) **M1** Less time or it decreases or (equilibrium) reached faster (ie **M1** is a reference to time taken)

*If **M1** is 'more time / it increases' or 'no effect', then **CE=0** for the clip.*

*Reference to faster / increased rate / increased speed alone penalises **M1**, but mark on **M2** and **M3**.*

**M2** More particles / molecules in a given volume / space

**OR** the particles / molecules are closer together

*If **M1** is blank, then look for all three marks in the text.*

**M3** More successful / productive collisions in a given time

**OR** more collisions with  $E > E_{\text{act}}$  in a given time



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**OR** more frequent successful / productive collisions**OR** increased / greater successful / productive collision frequency / rate*Ignore reference to reactants / products.**Penalise **M3** if an increase / decrease in the value of  $E_{Act}$  is stated.*

3

**[8]****M5.(a)** Mol of **E** 1.6(00)*Ignore extra zeros.*

1

Mol of **F** 0.2(00)

1

(b) 
$$K_c = \frac{[G]^2}{[E][F]^2}$$

*Penalise expression containing V.**Penalise missing brackets or ( ).*

1

mol<sup>-1</sup> dm<sup>3</sup>*If  $K_c$  wrong, allow units consequential to their  $K_c$ , but no marks in (c) unless correct  $K_c$  used in (c).*

1

(c) 
$$K_c = \frac{(0.85/1.5)^2}{(2.50/1.5)(1.20/1.5)^2}$$

*Vol missed or used wrongly – no marks.**If  $K_c$  correct in (b) but squared term missed here, no further marks.*

1

= 0.3(01) Allow 0.299–0.304





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*Ignore units.*

1

(d) M1 Decrease

*If M1 is incorrect CE=0 for the clip.*

*If M1 is blank, mark on and seek to credit the correct information in the explanation.*

1

M2 More moles on LHS / reactants or fewer / less moles on RHS / products (allow correct ratio 3:2)

*M2 not just a generic statement 'shifts to more moles'.*

1

M3 (Equilibrium) shifts / moves either to oppose reduction in pressure / or to increase the pressure

*M3 depends on a correct statement for M2.*

*Not 'favours'.*

*Allow 'to oppose change' only if reduction in pressure noted.*

1

(e) M1  $T_1$

*If M1 is incorrect, CE=0 for the clip.*

*If M1 is blank, mark on and seek to credit the correct information in the explanation.*

1

M2 (Forward\*) reaction is exothermic  
**OR** Backward reaction is endothermic

*\*Assume answer refers to forward reaction unless otherwise stated.*

1

M3 (at  $T_2$  or lower temperature)

(Equilibrium) shifted / moved to oppose reduction in temp

**OR**

at  $T_1$  or higher temp, (Equilibrium) shifted / moved to oppose



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(increase in temp)

*M3 depends on a correct statement for M2*

*Allow "to oppose change" only if change in temperature is stated.*

*Not 'favours'.*

1  
[12]

**M6.(a)** (i) M1 c(oncentrated) phosphoric acid / c(onc.)  $H_3PO_4$

**OR** c(oncentrated) sulfuric acid / c(onc.)  $H_2SO_4$

*In M1, the acid must be concentrated.*

*Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.*

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants

**OR** pass the gases over the catalyst several / many times

*In M2, ignore "remove the ethanol".*

*Credit "re-use".*

2

(ii) M1

(By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction

**M2 depends on a correct statement of M1**

The equilibrium moves / shifts to

- oppose the addition of / increased concentration of / increased moles / increased amount of water / steam
- to decrease the amount of steam / water

**Mark M3 independently**

M3 Yield of product / conversion increase **OR** ethanol increases / goes up / gets more

3

(iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

**M2 At higher pressures**

More / higher cost of electrical energy to pump / pumping cost

**OR**

Cost of higher pressure equipment / valves / gaskets / piping etc.

**OR** expensive equipment

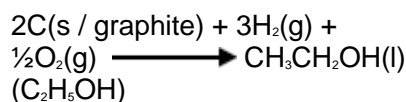
*Credit all converse arguments for M2*

2



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(b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation

*Not multiples but credit correct state symbols in a correctly balanced equation.*

*Penalise C<sub>2</sub>H<sub>6</sub>O but credit correct state symbols in a correctly balanced equation.*

2

(c) (i) M1 The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is burned / combusts / reacts completely in oxygen

**OR** burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states

**OR** (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298

K

*For **M3***

*Ignore reference to 1 atmosphere*

3

(ii) M1

*Correct answer gains full marks*

$$\underline{\Sigma B(\text{reactants}) - \Sigma B(\text{products}) = \Delta H}$$

*Credit 1 mark for (+) 1279 (kJ mol<sup>-1</sup>)*

OR

$$\underline{\text{Sum of bonds broken} - \text{Sum of bonds formed} = \Delta H}$$

OR

$$\text{B(C-C)} + \text{B(C-O)} + \text{B(O-H)} + 5\text{B(C-H)} + 3\text{B(O=O)} \text{ (LHS)}$$

$$- 4\text{B(C=O)} - 6\text{B(O-H)} \text{ (RHS)} = \underline{\Delta H}$$

M2 (also scores **M1**)

$$348+360+463+5(412)+3(496) \text{ [LHS} = \mathbf{4719}]$$

$$(2060) \quad (1488)$$

$$- 4(805) - 6(463) \text{ [RHS} = - \mathbf{5998}] = \Delta H$$

$$(3220) \quad (2778)$$

OR using only bonds broken and formed (**4256 - 5535**)

*For other incorrect or incomplete answers, proceed as follows*



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- check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)
- If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1**

M3

$$\Delta H = -1279 \text{ (kJ mol}^{-1}\text{)}$$

Allow a maximum of one mark if the only scoring point is LHS = 4719 OR RHS = 5998

Award 1 mark for +1279

**Candidates may use a cycle and gain full marks**

3

- (d) (i) Reducing agent OR reductant OR electron donor  
OR to reduce the copper oxide  
 Not "reduction".  
 Not "oxidation".  
 Not "electron pair donor".

1

- (ii) CH<sub>3</sub>COOH

1

[17]

- M7.(a) (i) mol H<sub>2</sub> = 0.47

1

$$\text{mol I}_2 = 0.17$$

If answers reversed, ie

$$\text{mol H}_2 = 0.17$$

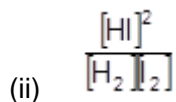
$$\text{mol I}_2 = 0.47$$

then allow one mark (for second answer).

1



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Penalise expression containing V  
But mark on in (a)(iv)

**Penalise missing square brackets in this part (and not elsewhere in paper) but mark on in (a)(iv)**

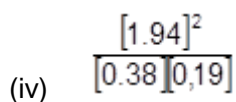
1

(iii) equal number of moles (on each side of equation)

**OR**

equal moles (top and bottom of Kc expression)

1



Ignore V

*If Kc wrong in (a)(ii) (wrong powers or upside down etc) no marks here*

1

$$= 52(.1)$$

1

(b) (i) **D**

1

(ii) **B**

1

(iii) **A**

1

(iv) **C**

1



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**[10]**

M8. (a)  $K_p = \frac{P_{\text{SO}_2} \times P_{\text{Cl}_2}}{P_{\text{SO}_2\text{Cl}_2}} \quad (1)$  1

(b)  $0.25 + 0.75 + 0.75 = 1.75 \quad (1) \quad (1)$  2

(c) (i)  $p = \text{Total pressure} \times \text{mol fraction} \quad (1)$

(ii) *Partial of SO<sub>2</sub>Cl<sub>2</sub>*:  $125 \times \frac{0.25}{1.75} = 17.9 \text{ kPa} \quad (1)$

*Partial pressure of Cl<sub>2</sub>*:  $125 \times \frac{0.75}{1.75} = 53.6 \text{ kPa} \quad (1) \quad (1)$  5

(d)  $K_p = \frac{53.6 \times 53.6}{17.9} \quad (1) = 161 \quad (1) \text{ kPa} \quad (1)$  3

(e) *Effect on K<sub>p</sub>*: increase **(1)**  
*Explanation*: increase T sends equilibrium in endothermic direction **(1)** 2

(f) no effect **(1)** 1

**Notes**

(a) If K<sub>p</sub> has [ ] lose mark in (a) but allow full marks in (d)

If K<sub>p</sub> wrong/upside down etc, allow max 2 in (d) for substitution of numbers **(1)**  
and consequential units **(1)**



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(b) Mark for moles of  $\text{SO}_2\text{Cl}_2$  can be scored in part (c) (ii) if not gained in (b)

1.75 get **(2)**

If moles of  $\text{SO}_2\text{Cl}_2 = 1$ , this is a Chemical Error, hence a 2 mark penalty

- If total moles given in (b) = 1.75, this scores [2] in (b); but if the no moles of  $\text{SO}_2\text{Cl}_2 = 1$  in (c)(ii), lose both marks in (c)(ii) for pp of  $\text{SO}_2\text{Cl}_2 = (1/1.75) \times 125$ ,  
i.e. the 2 mark penalty is in (c)(ii).
- If total moles given in (b) = 2.5, score zero in (b), but can gain full marks in (c)(ii) consequentially, i.e. the 2 mark penalty is in (b).
- If moles of  $\text{SO}_2\text{Cl}_2 = 1$  and total in (b) does not equal 2.5, still lose both in (b)  
but can get all 4 conseq in (c)(ii) for  $1/x$  etc and  $0.75/x$  etc

(c) (i) Allow "Total pressure = sum of partial pressures" for **(1)** or  $p_A = x_A \times p_{\text{tot}}$

(ii) First mark is for mole fraction.  
If either number in either mole fraction is not consequential on (b),  
then lose both marks for that partial p.

(d) If  $p_{\text{Cl}_2}$  is not equal to  $p_{\text{SO}_2}$  or any number used in  $K_p$  is not conseq on (c)(ii),  
allow units only

SIG FIGS; must be 3 sig figs in (b) but then allow 2 sig figs in (c) and (d);  
(ignore extra figs) but penalise incorrect rounding

(e) If effect wrong, no marks for explanation.  
If effect missing, e.g. answer states "equilibrium shifts to right", mark on.  
In the explanation, the word "endothermic" (or its equivalent) is essential.



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**M9.** (a) (i) Moles of  $PCl_3$ :  $0.345 - 0.166 = 0.179$  (1)

Moles of  $Cl_2$ :  $0.268 - 0.166 = 0.102$  (1)

3 sig figs

(ii) 0.447 (1)

allow 2 sig figs

conseq on (i)

3

(b) Mole fraction of  $PCl_3$ :  $0.179/0.447$  (1) = 0.4(00)

Partial pressure of  $PCl_3$ :  $pp = \text{mol } f^{\text{n}} \times \text{total } P$  (1)  
=  $0.400 \times 225 = 90$  (1) kPa (1)

3

(c) (i) 
$$K_p = \frac{P_{PCl_3}}{P_{PCl_5} \times P_{Cl_2}}$$
 (1)  
ignore brackets except [ ]  
must show P

(ii) 
$$K_p = \frac{83.6}{90.1 \times 51.3}$$
 (1) =  $1.8(1) \times 10^{-2}$  (1) kPa<sup>-1</sup> (1) (or  $1.81 \times 10^{-5}$  Pa<sup>-1</sup>)  
If 83.6 and 51.3 wrong way round, AE - 1,  
answer =  $6.81 \times 10^{-3}$   
If  $K_p \times$  in (i) allow max 2 for substitution of numbers  
and conseq units

4

(d) (i) increased (1)

(ii) increased (1)

2

[12]

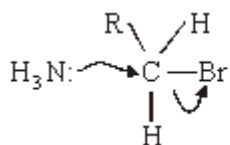
Organic points

(1) Curly arrows: must show movement of a pair of electrons,  
i.e. from bond to atom or from lp to atom / space  
e.g.

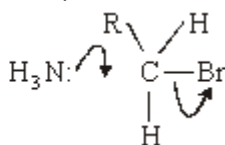




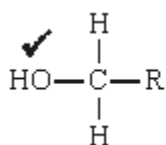
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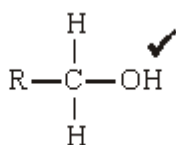
OR

(2) Structures

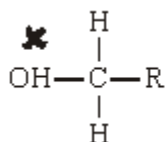
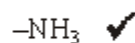
penalise sticks (i.e.  $\begin{array}{c} | \\ \text{---C---} \\ | \end{array}$ ) once per paper



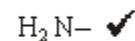
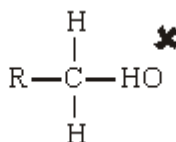
or



or



or



etc

Penalise once per paper

allow  $\text{CH}_3\text{---}$  or  $\text{---CH}_3$  or  $\begin{array}{c} \text{CH}_3 \\ | \end{array}$  or  $\text{CH}_3$   
or  $\text{H}_3\text{C---}$

**M10.** (a) (i) 0.86 (1)

(ii) total moles = 0.86 + 0.43 + 0.085 = 1.375 (1)

$$\therefore \text{mole fraction of H}_2 = \frac{0.86}{1.375} = 0.625 \text{ (1)}$$

(0.62 - 0.63)

Conseq on (i)



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- (iii)  $p_p = \text{mole fract}^n \times \text{total } P$  **(1)**  
 $= 0.625 \times 1.75 \times 10^4$   
 $= 1.09 \times 10^4$  (kPa) **(1)**  
*or 1.1(0)*  
*Ignore units*  
*Conseq on (ii)*

5

(b) (i)  $K_p = \frac{P_{\text{CH}_3\text{OH}}}{P_{\text{H}_2}^2 \times P_{\text{CO}}}$  **(1)**  
*Penalise [ ]*

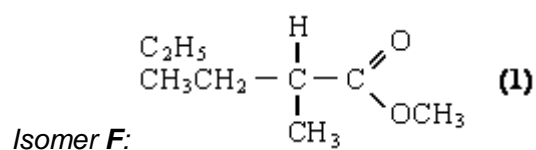
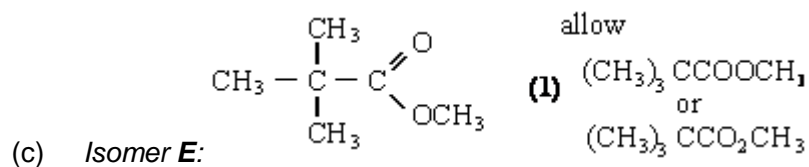
(ii)  $K_p = \frac{2710}{(12300)^2 \times (7550)} = 2.37$  (2.4)  $\times 10^{-9}$  **(1)**  
*OR 2.37  $\times 10^{-15}$*

*Units: kPa<sup>-2</sup>* **(1)**

*or Pa<sup>-2</sup>*

*not conseq to wrong K<sub>p</sub> expression*

3



2

**[10]**



## Kc &amp; Kp Past Paper ANSWERS

**M11.(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  $\text{CO}_2$  (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



## Kc &amp; Kp Past Paper ANSWERS

- (f) Stage 1: moles of components in the equilibrium mixture  
*Extended response question*



Initial moles	1.0	3.0	0	0
Eqm moles	$(1-0.86)$ $= 0.14$	$(3-3 \times 0.86)$ $= 0.42$	0.86	0.86

1

Stage 2: Partial pressure calculations

Total moles of gas = 2.28

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

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

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



## Kc &amp; Kp Past Paper ANSWERS

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

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

1

**[16]****M12.**

(a) (i)  $(K_p) = (p_z)^2 / (p_x)(p_y)^3$   
*(penalise use of square brackets, allow ())*

1

(ii) **X**  $(22-6)/4 = 4$  (MPa)  
*(mark is for value 4 only, ignore units)*

1

**Y** obtained by multiplying value for **X** by 3  
*(allow conseq on wrong value for X)*

1

**Y**  $4.0 \times 3 = 12$  (MPa)  
*(mark is for value 12 only)*

1

(iii)  $K_p = 6.0^2 / 4.0 \times 12.0^3 = 5.21 \times 10^{-3}$   
*(allow conseq on wrong values for X and Y e.g.  $6^2/3 \times 9^3 = 0.165$ )*

(if  $K_p$  wrong in (a)(i) CE)

1

$$\text{MPa}^{-2}$$

*(allow any unit of  $P^{-2}$  provided ties to P used for  $K_p$  value)*

1

(b) high pressure expensive (due to energy or plant costs)

1

(Rate is) slow (at lower temperatures)



## Kc &amp; Kp Past Paper ANSWERS

1

[8]

M13. (a) 12 (kPa)

1

$p_p = \text{mole fraction} \times \text{total pressure}$  or  $\text{mole fraction} = 12/104$

1

$= 0.115$

*(allow 0.12)*

1

(b) 68 (kPa)

1

(c) 
$$K_p = \frac{(p\text{SO}_3)^2}{(p\text{SO}_2)^2 \times (p\text{O}_2)}$$

*(If  $K_p$  wrong, allow consequential units only)*

*(penalise square brackets in expression but then mark on)*

1

$$= \frac{68^2}{24^2 \times 12}$$

1

$= 0.669$

*(Allow 0.67)*

*(Allow full marks in calculation consequential on their values in (a) and (b))*

1

kPa<sup>-1</sup>

1

(d) T<sub>2</sub>

*(Must be correct to score any marks in this section)*

1



### Kc & Kp Past Pape ANSWERS

#### Exothermic

1

Reduce T to shift equilibrium to the right  
or forward reaction favoured by low T  
or  $K_p$  increases for low T  
or low T favours exothermic reaction

1

(e) Increase

1

None

1

[13]

**M14.** (a) *(must state correct effect on yield or rate to score the reason mark)*

T effect: higher temp: yield greater or shifts equilibrium to right;

1

effect: higher temp: rate increased;

1

reason: endothermic

OR

more particles have  $E > E_a$ .

1

OR

more successful/productive collisions;

1

P effect: higher pressure: yield less or shifts equilibrium to left;

1

effect: higher pressure: rate increased;

reason: increase in gas moles L to R

OR

greater collision frequency;



## Kc &amp; Kp Past Paper ANSWERS

(Q of L mark)

1

(b) M1 equilibrium moles of CO = 62.8 - 26.2 = 36.6

1

M2 equilibrium moles of H<sub>2</sub> = 146 - 2(26.2) = 93.6

1

M3 total no moles = 36.6 + 93.3 + 26.2 = 156.4

1

M4 partial pressure = mole fraction x total pressure

1

$$M5 \quad K_p = \frac{P_{\text{CH}_3\text{OH}}}{P_{\text{CO}} \times P_{\text{H}_2}^2}$$

1

$$M6 \quad = \frac{\left(\frac{26.2}{156.4} \times 9.50\right)}{\left(\frac{36.6}{156.4} \times 9.50\right) \times \left(\frac{93.6}{156.4} \times 9.50\right)^2}$$

$$\frac{(0.168 \times 9.5)}{(0.234 \times 9.50) \times (0.598 \times 9.5)^2}$$

$$\frac{(1.59)}{(2.22) \times (5.69)^2}$$

1

M7 0.022(1)    2.2(l) × 10<sup>-8</sup>    2.2(l) × 10<sup>-14</sup>

1

M8 MPa<sup>-2</sup>    kPa<sup>-2</sup>    Pa<sup>-2</sup>

1

*If no subtraction lose M1, M2 and M3)  
 (If x2 missed in M2, lose both M2 and M3)  
 (If M1 gained but moles of H<sub>2</sub> = 73.2 (i.e. double CO),  
 M2 and M3 lost)  
 (If M1 gained but mol H<sub>2</sub> = 2(146 - 26.2), M2 and M3  
 lost)  
 (If M1 and M2 correct but M3 lost for CE, penalise M6  
 also)  
 (M4 can be gained from the numbers in the  
 expression for M6 even if these numbers are wrong)  
 (If K<sub>p</sub> contains [ ] lose M5 but then mark on)  
 (If chemically wrong expression for K<sub>p</sub>, lose M5, M6  
 and M7 (allow M8 conseq on their K<sub>p</sub>))*





## Kc &amp; Kp Past Paper ANSWERS

(If divided by 9.5, or not used 9.5 at all, lose M6 and M7 (and M4))

(If tried to convert to kPa and is factor(s) of 10 out, penalise in M6 and allow M8 for kPa<sup>-2</sup>)

**[14]**

<b>M15.</b>	(a)	M1	$K_p = \frac{(p_Y)^3 \cdot (p_Z)^2}{(p_W)^2 \cdot (p_X)}$	NB [ ] wrong	1
		M2	temperature		1
		M3	increase		1
		M4	particles have more energy or greater velocity/speed		1
		M5	more collisions with $E > E_a$ or more successful collisions		1
		M6	Reaction exothermic or converse		1
		M7	Equilibrium moves in the left		1
		Marks for other answers			
		Increase in pressure or concentration	allow M1, M5, M6	Max 3	
		Addition of a catalyst;	allow M1, M5, M6	Max 3	
		Decrease in temperature;	allow M1, M2, M6	Max 3	
		Two or more changes made;	allow M1, M6	Max 2	

- (b) (i) Advantage; reaction goes to completion, not reversible or faster 1

Disadvantage; reaction vigorous/dangerous  
(exothermic must be qualified)

or HCl(g) evolved/toxic  
or CH<sub>3</sub>COCl expensive

NB Allow converse answers

Do not allow reactions with other reagents e.g. water



Kc & Kp Past Paper ANSWERS  
or ease of separation

1

(ii)  $\Delta S = \Sigma S \text{ products} - \Sigma S \text{ reactants}$

1

□□□□□□□□  $\Delta S = (259 + 187) - (201 + 161)$

1

□□□□□□□□  $\Delta S = 84 \text{ (JK}^{-1} \text{ mol}^{-1})$  (Ignore units)  
Allow – 84 to score (1) mark

1

□□□□□□□□  $\Delta G = \Delta H - T\Delta S$

1

$= -21.6 - 298 \times 84/1000$   
 $= -46.6 \text{ kJ mol}^{-1}$  or  $-46\,600 \text{ J mol}^{-1}$

1

Allow (2) for – 46.6 without units  
(Mark  $\Delta G$  consequentially to incorrect  $\Delta S$ )  
(e.g.  $\Delta S = -84$  gives  $\Delta G = +3.4 \text{ kJ mol}^{-1}$ )

1

[15]