AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.10 EQUILIBRIUM CONSTANT KP

SCORE	PERCENTAGE
/139	%

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Q1.

(a) pp nitrogen = 0.25 × 30 = <u>7.5</u> kPa

1

pp hydrogen = 0.75 × 30 = <u>22.5 or 23</u> kPa

1

pp of ammonia = 0.8 × 150 = <u>120</u> kPa

1

(pp hydrogen + nitrogen = 150-120 = 30 kPa)
Alternative method
pp hydrogen = 0.15 × 150 = <u>22.5 or 23</u> kPa
pp nitrogen = 0.05 × 150 = <u>7.5</u> kPa

(b) $K_p = \dfrac{(ppNH_3)^2}{(ppN_2) \times (ppH_2)^3}$

Penalise [ ]

1

(c) $K_p = \dfrac{(1.10 \times 10^3)^2}{(1.50 \times 10^2)^3 \times 1.20 \times 10^2}$

No mark for this expression

1

= 0.0029 to 0.003(0) or 2.9×10^{-3} to $3(.0) \times 10^{-3}$

kPa^{-2}

If expression inverted in 02.2 allow 1 mark for kPa^2
Allow 2.9 to 3(.0) × 10^{-9} Pa^{-2}

1

(d) decrease/smaller/lower

If increase or no change, 0 marks
If blank, mark on

1

(Reaction/equilibrium) <u>shifts/moves/goes</u> in the endothermic direction (which is to the left)

Allow reaction is exothermic so equilibrium <u>moves</u> to the left side

1

to reduce the temperature OR oppose the increase in temperature

1

[9]

Q2.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

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Level 3 (5 – 6 marks)
All stages are covered and the explanation of each stage is generally correct and virtually complete. To access Level 3, statement 3a must be considered.
Answer is communicated coherently and shows a logical progression from stage 1 (including 1b) to stage 2 and stage 3

Level 2 (3 – 4 marks)
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.
Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3.

Level 1 (1 – 2 marks)
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.
Answer includes isolated statements but these are presented in a logical order, with sensible reasoning.

Level 0 (0 marks)
Insufficient correct chemistry to gain a mark.

Indicative chemistry content

Stage 1 – Deductions from graph
1a Yield increases as temperature increases (or converse)
1b After a certain temperature yield no longer increases
1c Yield decreases as pressure increases (or converse)

Stage 2 – Optimum temperature and explanation
2a High temperature results in high energy costs/expensive
2b (After a certain temperature) yield no longer increases therefore there is no gain in using a higher temperature
2c Optimum temperature is between 780-880oC

Stage 3 – Optimum pressure and explanation
3a Low pressure may be too slow
3b So compromise pressure required
3c Optimum pressure is 1000-2000kPa or moderate pressure used

6

(b) Moles of carbon monoxide 17.9

Allow 17.94

1

Moles of hydrogen 19.9

Allow 19.88

1

(c) $K_p = \dfrac{pp(CH_3OH)}{pp(CO) \times pp(H_2)2}$

ignore brackets
If K_p expression incorrect can only score M2 & M3 & M4

1

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Total moles of gas = (2.76 + 4.51 + 0.36) = 7.63

If CE in M2 allow ecf for M3, M4 and M6

If no total moles calculated then can only score M1 and M6

1

$pp(CO) = \frac{2.76}{7.63} \times 630$ (kPa) (= 228 (kPa))

$pp(H_2) = \frac{4.51}{7.63} \times 630$ (kPa) (= 372 (kPa))

$pp(CH_3OH) = \frac{0.36}{7.63} \times 630$ (kPa) (= 29.7 (kPa))

All 3 pp of CO, H_2 and CH_3OH = 2 marks

2 pp correct = 1 mark

2

$Kp = \frac{29.7}{228 \times (372)2} = 9.4(1) \times 10^{-7}$ or $9.4(1) \times 10^{-13}$ if *pp* in Pa

can also score M1 from this expression

Allow 9.39 to 9.50 × 10^{-7} (kPa^{-2})

1

kPa^{-2} or **Pa^{-2}** (if converted to 630 000)

*If no marks awarded allow M6 only for **kPa^{-2}** or **Pa^{-2}***

1

[14]

Q3.

D

[1]

Q4.

A

[1]

Q5.

(a) Bonds broken = 2(C=O) + 3(H–H) = 2 × 743 + 3 × H–H

Bonds formed = 3(C–H) +(C–O) + 3(O–H) = 3 × 412 + 360 + 3 × 463

Both required

1

–49 = [2 × 743 + 3 × (H–H)] – [3 × 412 + 360 + 3 × 463]

3(H–H) = –49 – 2 × 743 + [3 × 412 + 360 + 3 × 463] = 1450

Both required

1

H–H = 483 (kJ mol^{-1})

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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

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Initial moles	1.0	3.0	0	0
Eqm moles	(1–0.86) = 0.14	(3–3×0.86) = 0.42	0.86	0.86

1

Stage 2: Partial pressure calculations

Total moles of gas = 2.28

Partial pressures = mol fraction × p_{total}

1

p_{CO2} = mol fraction × p_{total} = 0.14 × 500 / 2.28 = 30.7 kPa

p_{H2} = mol fraction × p_{total} = 0.42 × 500 / 2.28 = 92.1 kPa

M3 is for partial pressures of both reactants

Alternative M3 =

pp_{CO2} = 0.0614 × 500

pp_{H2} = 0.1842 × 500

1

p_{CH3OH} = mol fraction × p_{total} = 0.86 × 500 / 2.28 = 188.6 kPa

p_{H2O} = mol fraction × p_{total} = 0.86 × 500 / 2.28 = 188.6 kPa

M4 is for partial pressures of both products

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Alternative M4 =

$pp_{CH3OH} = 0.3772 \times 500$
$pp_{H2O} = 0.3772 \times 500$

1

Stage 3: Equilibrium constant calculation
$K_p = p_{CH3OH} \times p_{H2O} / p_{CO2} \times (p_{H2})^3$

1

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

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

1

[16]

Q6.

D

[1]

Q7.

(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 × 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

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

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(Rate is) slow (at lower temperatures)

1

[8]

Q8.

(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;

(Q of L mark)

1

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

1

M2 equilibrium moles of H_2 = 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 $$K_p = \frac{PCH_3OH}{PCO \times P^2H_2}$$

1

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

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

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

1

M7 0.022(1) $2.2(l)\times10^{-8}$ $2.2(l)\times10^{-14}$

1

M8 MPa^{-2} kPa^{-2} Pa^{-2}

1

If no subtraction lose M1, M2 and M3)
(If ×2 missed in M2, lose both M2 and M3)
(If M1 gained but moles of H_2 = 73.2 (i.e. double CO), M2 and M3 lost)
(If M1 gained but mol H_2 = 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_p contains [ ] lose M5 but then mark on)
(If chemically wrong expression for K_p, lose M5, M6 and M7 (allow M8 conseq on their K_p))
(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^{-2})

[14]

Q9.

B

[1]

Q10.

(a) 12 (kPa)

1

pp = mole fraction × total pressure **or** mole fraction = 12/104

1

= 0.115

(allow 0.12)

1

(b) 68 (kPa)

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1

(c) $K_p = \dfrac{(pSO_3)^2}{(pSO_2)^2 \times (pO_2)}$

(If K_p wrong, allow consequential units only)

(penalise square brackets in expression but then mark on)

1

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

1

= 0.669

(Allow 0.67)

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

1

kPa^{-1}

1

(d) T_2

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

1

<u>Exothermic</u>

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]

Q11.

(a) *M1* $K_p = ({}_PY)^3 . ({}_PZ)^2 / ({}_PW)^2 . ({}_PX)$ *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

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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_3COCl expensive

NB Allow converse answers
Do not allow reactions with other reagents e.g. water or ease of separation

1

(ii) ΔS = ΣS products – ΣS reactants

1

ΔS = (259 + 187) – (201 + 161)

1

ΔS = 84 (JK^{-1} mol^{-1}) *(Ignore units)*
*Allow – 84 to score **(1)** mark*

1

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

1

= – 21.6 – 298 × 84/1000
= – 46.6 kJ mol^{-1} or – 46 600 J mol^{-1}

1

*Allow **(2)** for – 46.6 without units*
(Mark ΔG consequentially to incorrect ΔS)
(e.g. ΔS = –84 gives ΔG = +3.4 kJ mol^{-1})

1

[15]

Q12.

A

[1]

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Q13.

(a) $K_p = \frac{P_{SO_2} \times P_{Cl_2}}{P_{SO_2Cl_2}}$ **(1)**

1

(b) 0.25 + 0.75 + 0.75 = 1.75 **(1) (1)**

2

(c) (i) *p* = Total pressure × mol fraction **(1)**

(ii) *Partial of SO_2Cl_2*: $125 \times \frac{0.25}{1.75}$ = 17.9 kPa **(1)**

Partial pressure of Cl_2: $125 \times \frac{0.75}{1.75}$ = 53.6 kPa **(1) (1)**

5

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

3

(e) *Effect on K_p*: increase **(1)**
Explanation: increase T sends equilibrium in endothermic direction **(1)**

2

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

1

Notes

(a) If K_p has [ ] lose mark in (a) but allow full marks in (d)

If K_p wrong/upside down etc, allow max 2 in (d) for substitution of numbers **(1)** and consequential units **(1)**

(b) Mark for moles of SO_2Cl_2 can be scored in part (c) (ii) if not gained in (b)

1.75 get **(2)**

If moles of SO_2Cl_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 SO_2Cl_2 = 1 in (c)(ii), lose both marks in (c)(ii) for pp of SO_2Cl_2 = (1/1.75) × 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 SO_2Cl_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 $p_A = x_A \times p_{tot}$

(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.

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(d) If pCl_2 is not equal to pSO_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 "equm shifts to right", mark on.
In the explanation, the word "endothermic" (or its equivalent) is essential.

[14]

Q14.

(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 = mol f^n × total P **(1)**
= 0.400 × 225 = 90 **(1)** kPa **(1)**

3

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

(ii) $K_p = \dfrac{83.6}{90.1 \times 51.3}$ **(1)** = 1.8**(1)** × 10^{-2} **(1)** Kpa^{-1} **(1)** (or 1.81 × 10^{-5} Pa^{-1})
If 83.6 and 51.3 wrong way round, AE – 1,
answer = 6.81 × 10^{-3}
If K_p × in (i) allow max 2 for substitution of numbers and conseq units

4

(d) (i) increased **(1)**

(ii) increased **(1)**

2

[12]

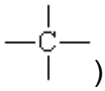
Organic points

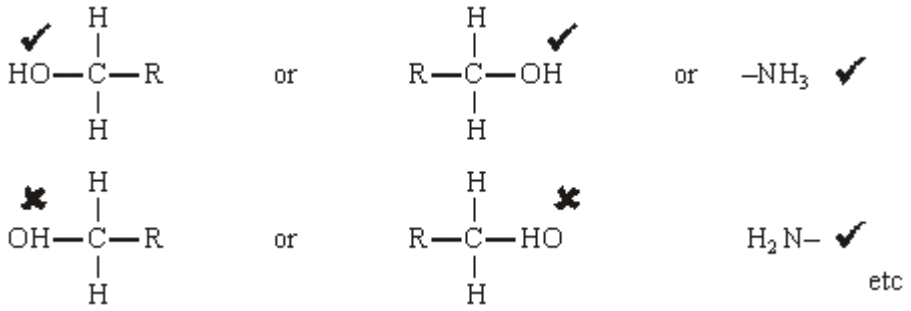
(1) Curly arrows: must show movement of a pair of electrons,
i.e. from bond to atom or from lp to atom / space
e.g.

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(2) Structures

penalise sticks (i.e. ) once per paper



Penalise once per paper

allow CH_3– or $–CH_3$ or  or CH_3
or H_3C–

Q15.

B

[1]

Q16.

C

[1]

Q17.

C

[1]

Q18.

D

[1]

Q19.

D

[1]

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Q20.

B

[1]

Q21.

B

[1]

Q22.

D

[1]

Q23.

(a) (i) 0.86 **(1)**

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

$\therefore$ **mole fraction of H_2** = $\frac{0.86}{1.375}$ = 0.625 **(1)**

(0.62 - 0.63)

Conseq on (i)

(iii) pp = mole fract^n × total P **(1)**
= 0.625 × 1.75 × 10^4
= 1.09 × 10^4 (kPa) **(1)**
or 1.1(0)
Ignore units
Conseq on (ii)

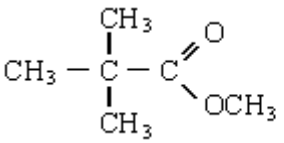
5

(b) (i) $K_p = \frac{P_{CH3OH}}{P^2_{H_2} \times P_{CO}}$ **(1)**
Penalise [ ]

(ii) $K_p = \frac{2710}{(12300)^2 \times (7550)}$ = 2.37 (2.4) × 10^{-9} **(1)**
OR 2.37 × 10^{-15}
Units: kPa^{-2} **(1)**
or Pa^{-2}
not conseq to wrong K_p expression

3

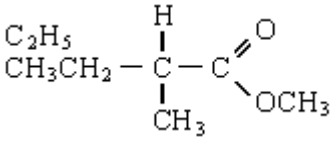
(c) *Isomer **E**:*



(1) allow $(CH_3)_3CCOOCH_3$ or $(CH_3)_3CCO_2CH_3$

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*Isomer **F**:*



(1)

2

[10]

Q24.

D

[1]

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Q1.

(a) Most students calculated the partial pressure of ammonia correctly but could not calculate the partial pressures of the other two gases; the idea that the total pressure is the sum of the partial pressures was missed by many students.

(b) Students answered this part well and most (70.8%) gave the correct expression; common errors included using square brackets, that denote concentration, or inverting the expression.

(c) Most students were able to calculate the equilibrium constant, but often the units were given as $mol^2\ dm^{-6}$.

(d) Most students could state that the value of K_p would decrease because the reaction was exothermic but failed to link this to Le Chatelier's principle and did not state that the equilibrium shifts/moves to oppose the increase in temperature.

Q2.

(a) Students answered this question quite well, with a good awareness of the range of temperatures and pressures needed. Most students failed to describe the information given in the graph; only the best students noted that the yield plateaued over about 850 °C. The relationship between pressure and rate was often missed and this also limited students' marks. Many students discussed conclusions that could be drawn from using *Le Chatelier's* Principle; this was not what the question was asking.

(b) Only a few students did not understand what was being asked for; most errors were either arithmetic errors or rounding errors.

(c) Many completely correct answers were seen (48.9% of students). Some students, however, could not calculate the total number of moles or could not calculate the partial pressures of the gases. Most students could write the expression for K_p but some forgot to square the partial pressure of hydrogen. Units were sometimes incorrectly given in moles.

Q7.

Good candidates were able to score high marks for this question. In part (a)(i) some weaker candidates gave an expression for K_c rather than for K_v. In part (a)(ii) a very common error was to give the partial pressure of X as 3.0 MPa, half of Z. The partial pressure of Y was then given as 9 MPa. Such answers were awarded only one out of three marks for recognising that the pressure of Y should be three times that of X. Consequential marking was adopted for part (a)(iii) and answers usually gained both marks though it was surprising to find that a candidate sometimes only squared the partial pressure of Y even though the same candidate had shown the pressure of Y cubed in part (a)(i). In part (b) the extra cost of using a high pressure was more often given than the disadvantage of a lower reaction rate.

Q8.

Part (a) was answered well as expected as the topic overlaps with qualitative equilibria in CHM2. Some candidates lost marks by discussing only the effect of increased temperature on the yield and not on the rate also. Several also suggested that the rate

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was unaffected or decreased by an increase of pressure. Part (b) was answered impressively by the better candidates, who were able to set out the answer clearly. Most were able to score marks for the expression for K_p or the definition of partial pressure (stated or inferred from a calculation). Too many, however, failed to realise that the amounts of the reagents at equilibrium were less than the initial amounts given. Even those who realised that the equilibrium amount of carbon monoxide was 62.8 – 26.2 mol did not always realise that, because of the 1:2 ratio in the equation, the equilibrium amount of hydrogen was 62.8 – (2 × 26.2) mol. However if this was their only error, six marks were still available. The pressure was given in MPa and the answer for K_p was expected with units MPa^{-2}. Many attempted unnecessarily to convert the pressure into kPa or even into Pa and got into difficulties with the powers often.

Q10.

This question was answered well by most candidates, particularly part (a). The 2:1 ratio or moles of sulphur dioxide to moles of oxygen was sometimes reversed, but marks were allowed in this part and in part (b) for correct use of their incorrect number of moles of oxygen. Most were able to write the expression for K_p correctly in part (c), although some were penalised for the use of square brackets. Full marks were available for correct substitution of wrong partial pressure values from parts (a) and (b). No marks were allowed for the calculation if the expression for K_p was wrong, but a mark was allowed for units correctly consequential on their expression. In part (d), better candidates were able both to predict and explain that T_2 was the lower temperature using the information given that the reaction was exothermic.
In part (e) most correctly stated that the yield of SO_3 would increase, but only the better candidates remembered that K_p is independent of pressure changes.

Q11.

Many candidates gave a correct expression for the equilibrium constant, K_p, for the reaction given in part (a). Some, who gave correct indices, lost a mark as they included square brackets, which are specific used to indicate concentration, in their expression. Identifying the one change which would increase the rate of reaction and decrease the value of K_p proved challenging but part marks were awarded for answers which addressed either of the two required changes. Candidates who gave more than one change of condition were able to score one mark for a correct K_p expression. There were many vague answers to part (b)(i), some of which assumed there were other reactants present with the most common example being water in Reaction 2. By contrast, (b)(ii) was very well answered with many candidates scoring full marks. Most candidates now remember to use either $kJ\ mol^{-1}$ or $J\ mol^{-1}$ throughout these calculations but a small number still failed to do this. Consequential marks were awarded in each part of the calculation.

Q13.

This question was well answered by many candidates and full marks were common for the most able. In part (a) a few candidates were penalised for using square brackets, e.g. $[SO_2]$ meaning concentration of SO_2 instead of using p for partial pressure, and a very few wrote the expression for K_p upside down. Part (b) caused the most problems. Many candidates forgot that, in order to produce 0.75 mol of Cl_2 (and 0.75 mol of SO_2), 0.75 mol of SO_2Cl_2 would be used up leaving only 0.25 mol in the equilibrium mixture. Both of the marks in part (b) were lost for this error, but full marks could be gained subsequently in parts (c)(ii) and (d) for correct working in the calculations. In part (e) most were able to deduce and explain that an increase in temperature would cause K_p to increase. However there were many who thought, incorrectly, that pressure had a similar effect.

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Q14.

The first three parts of this question were answered well even by some of the weaker candidates. Credit was given throughout for correct working consequential to errors in a previous part. Many candidates gained full marks in parts (a) and (b). In part (c)(i), most answers were correct except where square brackets were used. These are essential in K_c expressions but should not be used in expressions for K_p. Wrong substitution of the partial pressures values were sadly common but the correct units kPa^{-1} were usually given. After well-answered numerical sections, it was less common for the answers to both parts of (d) to be correct. Part (d)(i), which involved an increase in the volume of the vessel thereby causing a reduction in the total pressure, discriminated particularly well.

Q23.

The equilibrium parts of this question were generally answered well. In part (a)(i), the correct value of 0.86 was the most common answer but this was the least well-answered section of part (a). Full marks were awarded in parts (ii) and (iii) if the number of moles of hydrogen given in part (i) was used correctly. Even if the numbers were not used correctly, a mark was given in part (iii) for the correct statement that partial pressure equals mole fraction multiplied by the total pressure. In part (b) common errors were to include square brackets in the expression for K_p or to forget that the partial pressure of hydrogen should be squared. The units of K_p expected were kPa^{-2} but Pa^{-2} were accepted as long as the value given for K_p was 2.37×10^{-15}. Part (c) was poorly answered. Many structures were not esters at all and of those which were, few were methyl esters of C_5 acids. F was answered better than E but only the better candidates scored any marks here.

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