4.2 ANSWERS TO EXAM QUESTIONS

1. (a) (i) Increase (if wrong no further marks in part (i)) 1
higher *P* gives lower yield or moves to left 1
Eqm shifts to reduce *P* or eqm favours side with fewer moles 1

(ii) Endothermic if wrong no further marks in part (ii) 1
increase *T* increases yield or moves to right 1
Eqm shifts to reduce *T* or eqm favours endothermic direction 1

(b) (i) Moles of iodine = 0.023 1
Moles of HI = 0.172 1
If × 2 missed, max 1 in part (iv)
If wrong no marks in (i)

(ii) $K_c = \frac{[H_2][I_2]}{[HI]^2}$ must be square brackets (penalise once in paper) 1
– if round, penalise but mark on in (iv)
if K_c wrong, no marks in (iv) either but mark on from a minor slip in formula

(iii) V cancels in K_c expression
or no moles same on top and bottom of expression
or total moles reactants = moles products,
i.e. total no of moles does not change 1

(iv) $K_c = \frac{(0.023)^2}{(0.172)^2}$ 1
$= 0.0179$ or 1.79×10^{-2}
Conseq on (i) 1
Allow 0.018 or 1.8×10^{-2}

(v) $K_c = 55.9$ or 56 1
Conseq i.e. (answer to (iv))$^{-1}$

[13]

2. (a) $K_c = \frac{[Y][H_2O]^2}{[X][CH_3OH]^2}$ **(1)**
if K_c expression wrong lose units mark in (e) also
must be [ ]

1

(b) *Moles of **X***: 0.25 - 0.13 = 0.12 **(1)**
Moles of methanol: 0.34 - 0.26 = 0.08 **(1)**
Moles of water: 0.26 **(1)** 3

(c) Equal no. of moles on each side of equation **(1)**
OR V cancels out (provided not incorrectly qualified)

1

(d) *Calculation*: $K_c = \dfrac{\left(\frac{0.13}{V}\right)\left(\frac{0.26}{V}\right)^2}{\left(\frac{0.12}{V}\right)\left(\frac{0.08}{V}\right)^2}$ **(1)**

$= 11(.4)$ **(1)**

Can score all 3 conseq on (b) and (c)
If different values from (c) used allow units only
(conseq on correct K_c)

Units of K_c: none **(1)**
but lose this mark if K_c is wrong even if none given

3

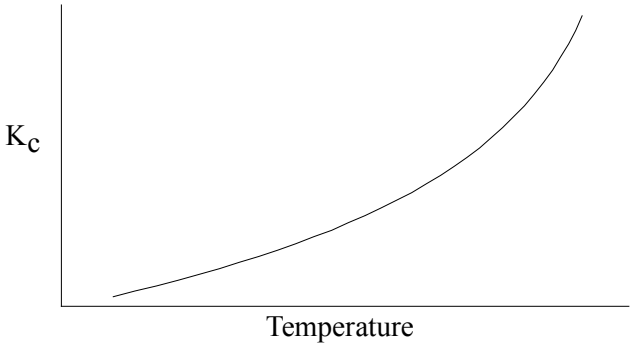
(e) decrease **(1)** 1

[9]

3. (a) *Equation* $N_2 + O_2 \rightleftharpoons 2NO$ **(1)**

K_c $[NO]^2 / [N_2]\,[O_2]$ **(1)** 2

(b)



As temperature increases K_c increases (or yield increases) **(1)**
Hence reaction endothermic **(1)** 2

(c) The product yield is very small **(1)**
Yield does not justify cost of producing high temp **(1)** 2

(d) (i) $2NO + O_2 \rightleftharpoons 2NO_2$ **(1)**

(ii) *Change in equilibrium position* Displaced to the right **(1)**
Change in equilibrium constant No change **(1)** 3

[9]

4. *(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; 1

(Q of L mark)

[6]

5. (a) $Kc = \frac{[H_2][I_2]}{[HI]^2}$ **(1)**

0.05 **or** 1/20 **(1)** 2

(b) (i) forward rate increases **(1)**

reverse rate increases **(1)**

allow 1 mark for just 'increased'
allow 2 marks for 'both increased' 2

(ii) no change **(1)** 1

(iii) no change **(1)** 1

[6]

6. (a) (i) Moles NaOH = mv/1000 = 1.50 × 72.5/1000 = 0.108 to 0.11 **(1)**
Moles of ethanoic acid at equilibrium = moles sodium hydroxide **(1)**
Moles ester = moles water (=moles acid reacted) **(1)**
= 0.200 – 0.108 = 0.090 to 0.92 **(1)**
Moles ethanol = 0.110 – 0.091 = 0.018 to 0.020 **(1)**
K_C = [Ester] [Water]/[Acid] [Alcohol] **(1)**
Allow if used correctly

$= (0.091)^2/0.109 \times 0.019 = 3.7$ to 4.9 **(1)** 7
Ignore units
NB Allow the answer 4 one mark as correct knowledge

(ii) Similar (types) of bond broken and made **(1)**
Same number of the bonds broken and made **(1)** 2
any number if equal
NB If a list given then the total number of each type of bond broken and made must be the same

[9]

7. (a) Homogeneous; All reactants in the same phase or state **(1)**

Dynamic; Continuous or 'on-going' **(1)**

Equilibrium: Concentrations of reactants and products constant or rates of forward and backward reactions equal **(1)**

Equation; $2NH_3 \rightleftharpoons N_2 + 3H_2$ (Must be decomposition) **(1)**

*K*c; $[N_2][H_2]^3/[NH_3]^2$ **(1)**

5

(b) Conditions:

decomposition favoured by high temp **(1)**

since the reaction endothermic or logical statement with application of Le Chatelier's principle **(1)**

decomposition favoured by low pressure **(1)**

2 mole gas giving 4 moles gas or more gas moles on right **(1)**

4

(c) In practise

low pressure means low production **(1)**
low pressure means low rate **(1)**

high temperature means high rate **(1)**
high temperature expensive **(1)**

Catalyst

equilibrium yield unaffected **(1)**
rates of forward and backwards reactions increased by an equal amount **(1)**
more hydrogen produced in a given time **(1)**

Max 6

[15]

3. Increased surface area **(1)**

more collisions **(1)** 2

[9]

(c) (i) $2H_2O_2 \rightarrow 2H_2O + O_2$ 1

(ii) Speeds up (alters the rate of) a chemical reaction 1
Remains unchanged (or not used up) 1

(iii) Remains unchanged (or not used up or not in the overall reaction equation) 1
Offers alternative reaction route (or acts as an intermediate) 1

[10]

5. (a) Graph starts at origin 1

Graph skewed to left and has decreasing gradient to maximum 1

Graph after maximum decreases in steepness, never touches *x* axis, levels out less than 5 mm from *x* axis. 1

(b) Minimum energy 1

To start a reaction (*or for a reaction to occur*) 1

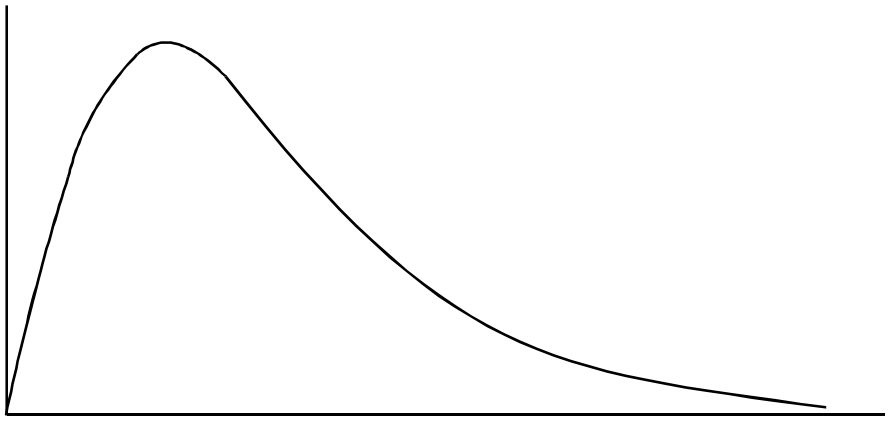
(c) Molecules gain energy (*or always some molecules have* $E > E_a$) 1

Due to collisions 1

(d) Decreases 1
E_a lowered **(1)**
By alternative route **(1)**
So more molecules have energy > E_a **(1)** max 2

[10]

7. (a) (i)



Number of molecules or particle **(1)**
NOT moles or mols or atoms
Not fraction or proportion

(Molecular) Energy **(1)** Not velocity

(ii) The total number of particles (or molecules) in the sample
OR the number of molecules present

(iii) No molecules have no energy
OR all molecules have some energy

Do not allow "if there are no molecules there is no energy" 4

(b) (i) The minimum energy required **(1)**

for a reaction to occur **(1)**
OR to start reaction or for a successful collision

(ii) Changes: Catalyst **(1)**

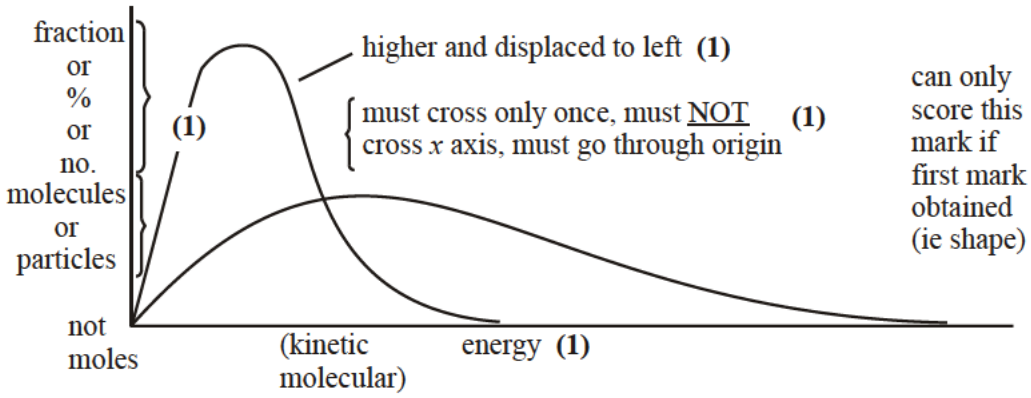
Explanation: Alternative route **(1),** with a lower activation energy **(1)**
OR a lower activation energy (1)
so more molecules can react (1)/more molecules have this energy

If change incorrect CE = 0

Allow answers anywhere in b (ii) 5

[9]

10. (a) 2



(b) See above 2

(c) Energy < E_a or must have enough energy (to react) **(1)** 1

(d) Increase concentration (or pressure) **(1)** 1

(e) Many **(1)** more molecules have E > E_a / enough energy **(1)** 2

NOT KE increases with T

(f) Lowers E_a **(1)**
alternative route **(1)** 2

[10]

12. (a) Activation energy;-
The minimum energy needed for a reaction to occur / start **(1)** 1

(b) Catalyst effect:-
Alternative route (or more molecules have Ea) **(1)**
Lower activation energy **(1)** 2

(c) Increase in moles of gas:-

Position of E_{mp} unchanged **(1)**
More molecules with E_{mp} **(1)**
Area under curve increases **(1)**
Molecules with $E \geq E_a$ increased **(1)**

Temperature decreased:-

Position of E_{mp} moves to the left **(1)**
More molecules with E_{mp} **(1)**
Area under curve unchanged **(1)**
Molecules with $E \geq E_a$ decreased **(1)**

Catalyst introduced:-

Position of E_{mp} unchanged **(1)**
Molecules with E_{mp} unchanged **(1)**
Area under curve unchanged **(1)**
Molecules with $E \geq E_a$ increased **(1)** 12

[15]

13. (a) the minimum energy; 1
Energy required for a reaction to occur; 1
(or to start a reaction or for successful collisions)

(b) axes labelled:- y: number *(or fraction or %)* of molecules *(or particles)*
x: energy *(or KE);* 1
curve starts at origin; 1
skewed to right; 1
approaches x axis as an asymptote; 1
(penalise a curve that levels off > 10% of max peak height or a curve that crosses the energy axis)

second curve displaced to the left (*and does not cross T_1 curve for a second time*) 1
and peak higher; 1

many fewer molecules; 1

fewer molecules have $E > E_a$ *;* 1
(can score this mark from suitably marked curves)

(b) molecules *(or particles or collisions)* do not have enough energy; 1
(or orientation may be wrong)

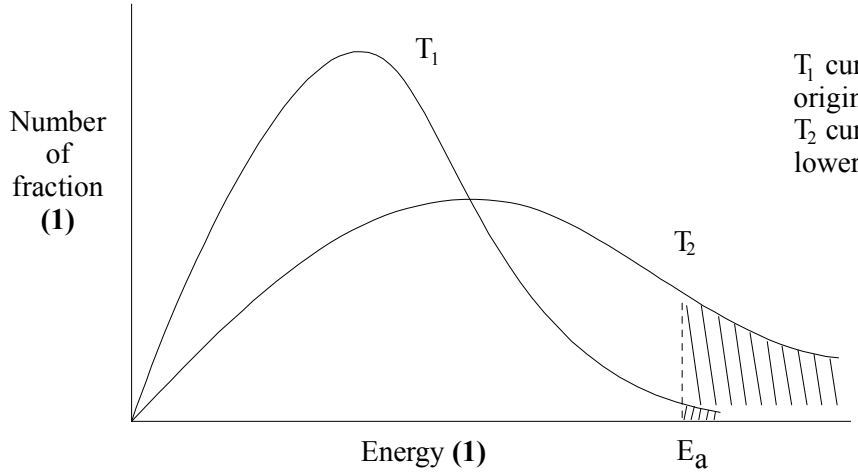
increase the pressure; 1
(or increase the concentration or reduce the volume)
increases the collision frequency; 1
(or more collisions)
(do not allow if stated to be due to increase in energy implied by temperature increase)

add a catalyst; 1

lowers <u>activation energy</u> (or E_a) *(Q of L mark);* 1

[15]

14.



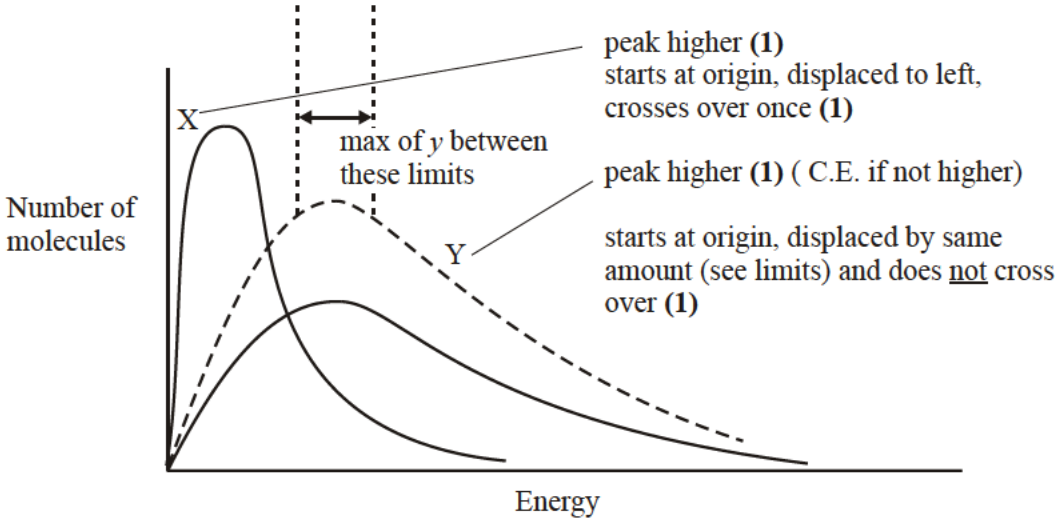
T_1 curve:
origin and shape **(1)**
T_2 curve:
lower and to right **(1)**

At T2: more molecules **(1)**
have sufficient energy **(1)**
plus reference to E_a or shaded area on graph **(1)**

Larger mass: more particles **(1)**
higher curve **(1)**
most probable energy is same **(1)**

[10]

15. (a) (i) (ii) 4



(b) (i) collide **(1)**
with sufficient energy (or $E \geq E_a$) **(1)** (*or with correct orientation*)

(ii) molecules (or particles) have more energy (or move faster) **(1)**
more molecules (or collisions) have $E \geq E_a$ (or sufficient energy) **(1)** 4

(c) (i) equilibrium reached **(1)**
(or rate forward reaction = rate backward)

(ii) Reaction is endothermic **(1)**
or ΔH +ve
or reverse reaction is exothermic

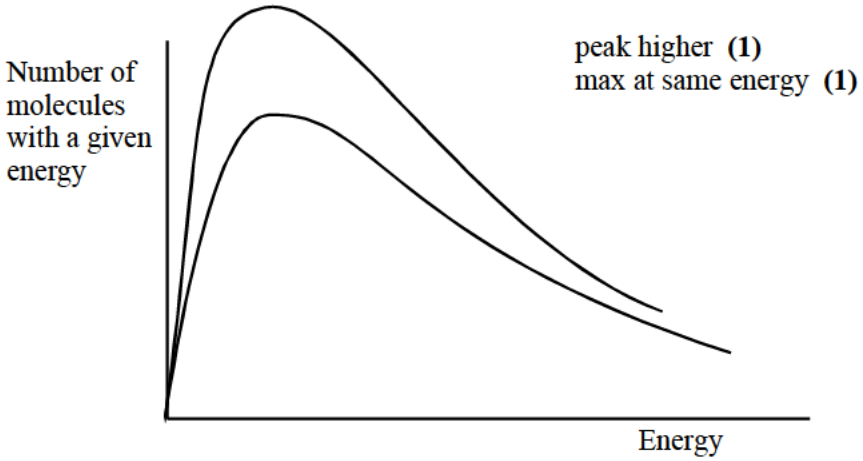
endothermic reaction favoured **(1)** 3
(or reaction shifts to R
or moves forward
or more products formed)

[11]

20. (a) (i) *Point* infinity or never **(1)**

Explanation no maximum energy for molecules **(1)**

(ii)



peak higher **(1)**
max at same energy **(1)**

(iii) no difference **(1)** 5

(b) *Requirement 1* Collision **(1)**

Requirement 2 With sufficient energy or correct orientation **(1)** 2

[7]

21. (a) Same 1

(b) (i) Decreases 1

More moles on left hand side 1

Equilibrium moves to increase the pressure 1
(Or to oppose the change or to compensate for low pressure)

(ii) Cost of producing high pressure **(1)**
Cost of plant to resist high pressure **(1)**
Correct safety factor with reason **(1)** max 2

(c) No change 1

Catalyst has no effect on equilibrium position 1
(Or catalyst affects rate of forward and backwards reactions equally)

(d) Negative 1

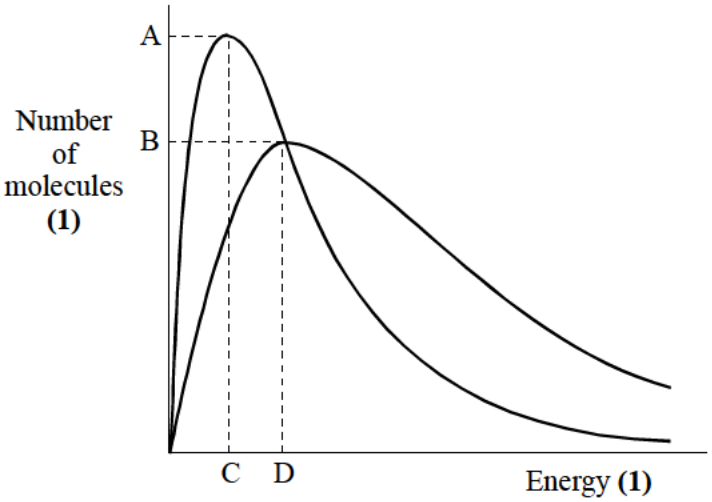
Reaction *(or equilibrium)* moves in the exothermic direction *(or to the right)* 1

In order to oppose the change *(or to raise the temperature)* 1

(e) Recycled (*or re-used or 'put back in'*) 1

[12]

22. (a) (i)



(ii) C **(1)** 3

(b) *Requirement 1* collisions **(1)**

Requirement 2 with sufficient energy **(1)** 2

(c) *Greater effect* Temperature **(1)**

Explanation For small ΔT, more molecules **(1)** have energy $\geq E_a$ **(1)** 3

[8]

23. (a) removal/loss of electrons 1

(b) no change 1
equal number of gaseous moles on either side 1
both sides affected equally 1
increases 1
equilibrium moves to lower the temperature/oppose the change 1
endothermic reaction favoured /forward reaction is endothermic 1

(c) (i) +2 1
+5 1

(ii) $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$ 1

(iii) $Ag \rightarrow Ag^+ + e^-$ 1

(iv) $NO_3^- + 4H^+ + 3Ag \rightarrow NO + 2H_2O + 3\ Ag^+$ 1

[12]

24. (a) 12 (kPa) 1

pp = mole fraction × total pressure **or** mole fraction = 12/104 1

= 0.115 1

(allow 0.12)

(b) 68 (kPa) 1

(c) $K_p = \dfrac{(pSO_3)^2}{(pSO_2)^2 \times (pO_2)}$ 1

(If K_p wrong, allow consequential units only)

(penalise square brackets in expression but then mark on)

$= \dfrac{68^2}{24^2 \times 12}$ 1

= 0.669 1

(Allow 0.67)

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

kPa^{-1} 1

(d) T_2 1

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

<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]

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.

(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.

26. (a) An <u>equilibrium</u> opposes change **(1)** 1

(b) (i) *Effect on yield of hydrogen:* decreases **(1)**
Note C.E. if not decrease, but mark on if no answer

Explanation: pressure lowered (or increase opposed) **(1)**
by favouring fewer moles (of gas) **(1)**

(ii) *Effect on yield of hydrogen*: increase **(1)** 6
CE if wrong as above

Explanation: pressure / concentration / reactants / steam reduced **(1)**
by shifting to right **(1)**
or steam removed or forward reaction favoured

(c) *Reason 1*: cost of high temperature / energy **(1)**

Reason 2: cost of plant (to resist high T) too high **(1)** 2
OR plant could not contain high T

[9]

27. (a) rate forward reaction = rate backward reaction **(1)**
concentration remains constant **(1)**
NOT 'Equal',
Allow 'The same' if clear that means constant

2

(b) fewer moles (of gas) on R.H.S **(1) (or converse)**
(methanol favoured) by reducing applied pressure **(1)**
Or removing constraint

2

(c) Power / energy required to provide high pressure / pumping **(1)**
Strong pressure vessel / or equipment **(1)**
High maintenance costs
Any two

2

(d) Effect: decreases **(1)**
Explanation: reaction exothermic **(1)**
system tries to lower T or remove constraint or oppose the change
or endothermic reaction favoured 3

(e) to speed up reaction **(1)**
or otherwise to slow
or takes too long
or to give more molecules $E > E_A$

1

[10]

28. (a) mark labelled **X** on curve **A** where curve **C** joins **A**; 1

(b) equilibrium opposes a change; 1
(Q of L mark)

(c) **B** 1

more ammonia is produced (or yield increases); 1
fewer moles (of gas) on right (or 4 mol goes to 2 mol); 1
equilibrium moves to oppose increase in pressure (or oppose change); 1

(d) **C** 1

amount of ammonia (or yield or equilibrium) unchanged; 1
reaction is faster; 1

[9]

29. (a) (i) All (reagents) (reagents) are in the same phase/state/are gases **(1)**

(ii) The forward and backward reations are occurring **(1)**

at the same/equal rate **(1)**

or concentrations of reactants (and products) are constant **(1)**

and reaction is continuous **(1)**
Note: "concentrations of reactants and products are the same" is incorrect

3

(b) (i) (Concentration of hydrogen /products) increased **(1)**
NB if a product stated this must be H_2

Equilibrium moves to right / forward reaction favoured **(1)**

to remove added water / system reacts to oppose change **(1)**
Mark CE if effect wrong. Do not allow "rate" answers

(ii) (concentration of hydrogen / products) increased **(1)**

Equilibrium moves to right / forward reaction favoured **(1)**

Reaction exothermic / gives out heat / moves to oppose change **(1)**

*Allow max **(1)** for exothermic if other answers incorrect* 6

(c) None **(1)**

Rates of both forward and backward reactions increased / changed **(1)**

by same amount **(1)**

Allow; Activation energy of forward and backward reactions lowered by the same amount (1)

CE if effect wrong

3

[12]

30. (a) (i) *Temperature* change decrease **(1)**

Explanation exothermic reaction **(1)**

(ii) *Pressure change* decrease **(1)**

Explanation fewer moles of gas on l.h.s **(1)** 4

(b) (i) *Temperature* to increase reaction rate **(1)**

Pressure to increase reaction rate **(1)**

(ii) *Reason 1* large surface area **(1)**

Reason 2 lower cost in expensive Pt **(1)** 4

(c) (i) enthalpy of formation **(1)**

(ii) <u>standard</u> conditions **(1)**

1 bar pressure and stated (fixed) temperature **(1)**

reactants and products in <u>standard states</u> **(1)**

(iii) Pollutants (acid rain) – NO_x

produced by combustion engines

(iv) decomposition is exothermic **(1)**

Low T reduces effect of heat evolved **(1)** 7

(d) NO produced in Stage 3 **(1)**

can be recycled to Stage 2 **(1)** 2

[17]

32. (a) (i) *Rates:* Rates are equal, forward and backward **(1)**
Concentrations: Concentrations are constant **(1)**
Q of L mark

(ii) *Equilibrium yield:* Decreases **(1)**
if wrong allow max 1 for a correct moles statement

Explanation: More moles / molecules of product (or 2 → 4) **(1)**
Reaction / equilibrium moves to left / reduce constraint **(1)**
NOT "volume" answers
Allow one for "Reaction favours fewer molecules"

(iii) Enthalpy of reaction is positive / endothermic **(1)**

(iv) Both forward and backward rates changed / increased **(1)**
by equal amount (same proportion) **(1)**
allow one for "Ea of forward and backward reactions reduced by an equal amount"

8

(b) (i) The reaction is exothermic **(1)**
High temperature gives a low equilibrium yield **(1)**
Rate of reaction higher at higher temperature **(1)**
An "equilibrium statement" needed e.g. low temp favours the reaction
Do not allow answers based on cost of higher temperature etc

(ii) Higher pressure gives a higher yield **(1)**
4 moles of gaseous reactant form 2 moles of gaseous product **(1)**
Higher pressure generation or equipment is expensive to produce **(1)**
Equilibrium statement required
Cost factor
N.B. NOT a safety answer

6

[14]

33. (a) (i) enthalpy change when 1 mol of a substance (or compound) (QL mark) 1
is (completely) burned in oxygen (or reacted in excess oxygen) 1
at 298 K and 100 kPa (or under standard conditions) 1

(ii) heat produced = mass of water × Sp heat capacity $x\Delta T$ (or $mc\Delta T$) 1
= 150×4.18×64 (note if mass = 2.12 lose first 2 marks then conseq)
= 40100 J or = 40.1 kJ (allow 39.9-40.2 must have correct units) 1
moles methanol = mass/M_r = 2.12/32 (1) 1
= 0.0663

ΔH = – 40.1/0.0663 = – 605 kJ (mol^{-1}) 1
(allow –602 to –608 or answer in J)
(note allow conseq marking after all mistakes but note use of 2.12 g loses 2 marks

(b) (i) equilibrium shifts to left at high pressure 1
because position of equilibrium moves to favour fewer moles (of gas) 1

(ii) at high temperature reaction yield is low (or at low *T* yield is high) 1
at low temperature reaction is slow (or at high *T* reaction is fast) 1
therefore use a balance (or compromise) between rate and yield 1

(c) $\Delta H = \Sigma \Delta H_c^{\ominus}$(reactants) – $\Sigma \Delta H_c^{\ominus}$(products) (or correct cycle) 1

$\Delta H_c^{\ominus}(CH_3OH) = \Delta H_c^{\ominus}(CO) + 2 \times \Delta H_c^{\ominus}(H_2) - \Delta H$ 1
$= (-283) + (2 \times -286) - (-91)$ (mark for previous equation or this)
$= -764$ (kJ mol^{-1}) (*units not essential but lose mark if units wrong)* 1
(note + 764 scores 1/3)

[15]

34. (a) Homogeneous; All reactants in the same phase or state **(1)**

Dynamic; Continuous or 'on-going' **(1)**

Equilibrium: Concentrations of reactants and products constant or rates of forward and backward reactions equal **(1)**

Equation; $2NH_3 \rightleftharpoons N_2 + 3H_2$ (Must be decomposition) **(1)**

*K*c; $[N_2][H_2]^3/[NH_3]^2$ **(1)**

5

(b) Conditions:

decomposition favoured by high temp **(1)**

since the reaction endothermic or logical statement with application of Le Chatelier's principle **(1)**

decomposition favoured by low pressure **(1)**

2 mole gas giving 4 moles gas or more gas moles on right **(1)**

4

(c) In practise

low pressure means low production **(1)**
low pressure means low rate **(1)**

high temperature means high rate **(1)**
high temperature expensive **(1)**

Catalyst

equilibrium yield unaffected **(1)**
rates of forward and backwards reactions increased by an equal amount **(1)**
more hydrogen produced in a given time **(1)**

Max 6

[15]

35. (a) **Increase in temperature:**

Yield is increased **(Allow if for H_2 (g) or products) (1)**
Reaction endothermic **(1)**
Equilibrium moves to the right **OR** forward, **OR** Equilibrium moves to oppose change **OR** to absorb heat **(1)**

If "Yield statement" incorrect allow max one if reaction stated to be endothermic

Increase in pressure:

Yield is decreased **(Allow if for H_2 (g) or products) (1)**
Increase in moles of gas **or** 2 moles increased to 4 moles **or** more moles on right **(1)**
Equilibrium moves to the left **OR** backwards, **OR** Equilibrium moves to oppose change **OR** to reduce pressure **(1)**

If "Yield statement" incorrect allow max one if number of moles change is correct.

6

(b) **Equilibrium yield:**
Unaffected **or** equilibrium unchanged **(1)**
Rate or speed increased **(1)**
Forward and backwards reactions equally or by the same amount **(1)**

Amount of hydrogen produced:
More hydrogen produced **(1)**

4

[10]

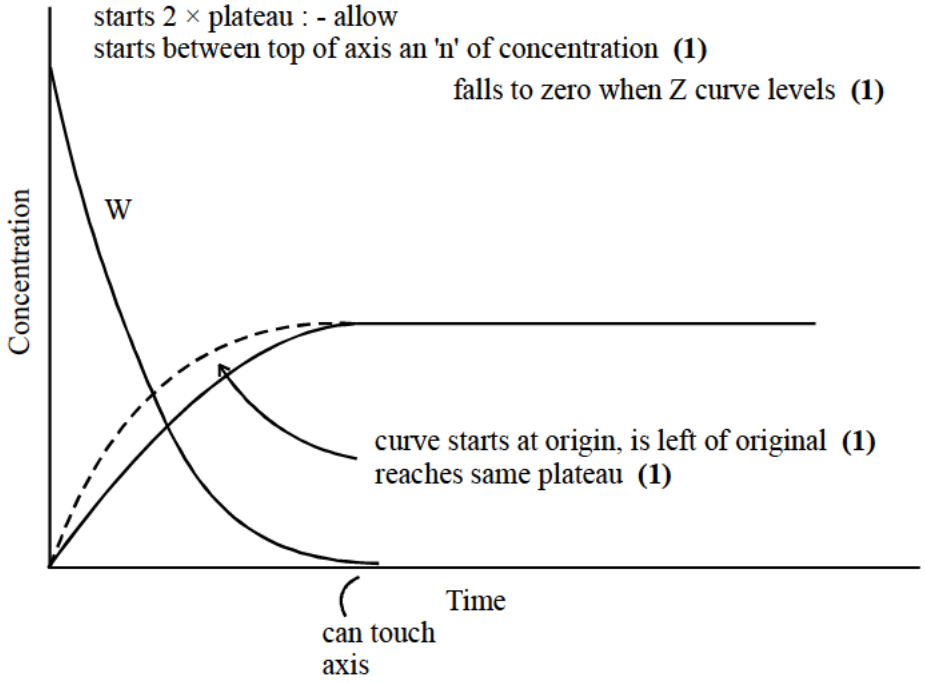
36. (a) <u>minimum</u> energy **(1)**
required before a reaction can occur or go or start **(1)** 2

(b) speeds up (changes) reaction rate **(1)**
without being (chemically) changed **(used up) (1)** 2

(c) provides alternative reaction route **(1)**
with a lower activation energy **(1)**

in (b) and (c) reward 4 marks for 4 points wherever found 2

(d) (i)



starts 2 × plateau : - allow
starts between top of axis an 'n' of concentration **(1)**

falls to zero when Z curve levels **(1)**

curve starts at origin, is left of original **(1)**
reaches same plateau **(1)**

(ii)

(iii) fewer collisions **(1)**
W used up **(1)**
or reactants
or reagents
or fewer particles

6

[12]

5.3 questions ms

1. (a) gains electrons **(1)** 1

[1]

2. (a) (i) Fe^{2+} 1

(ii) F_2O 1

(iii) Fe^{2+} 1

Cl^- 1

Use list principle if more than two answers

(b) (i) e.m.f. = *E*(rhs) – *E*(lhs) 1

= 1.52 – 0.77 = 0.75

(0.75 scores first mark also) 1

(ii) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ 1

(iii) Decrease 1

(Increase is CE, no further marks)

Equilibrium (or reaction) shifts to R 1

(or L if refers to half equation in table)

(or in favour of more Fe^{3+})

(or more Fe^{3+} formed)

(or more electrons formed)

Electrode potential (for Fe^{3+}/Fe^{2+}) less positive (or decreases) 1

[10]

3. (a) Fe^{2+} or Fe(II) 1

(b) (i) 6 or (VI) 1

(ii) 3 or (III) 1

(c) (i) 0.5 1

(ii) $2Mn^{2+} + 8H_2O + 5S_2O_8^{2-} \rightarrow 10SO_4^{2-} + 2MnO_4^- + 16H^+$

Both SO_4^{2-} and MnO_4^- on right 1

Balanced 1

[13]

4. (a) (i) 0.60 V 1

(ii) $H_2O + H_2SO_3 \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ 1

(b) (i) $2IO_3^- + 2H^+ 5H_2O_2 \rightarrow 5O_2 + I_2 + 6H_2O$ Species 1
Balanced 1

(ii) The concentration of the ions change or are no longer standard or the e.m.f is determined when no current flows 1

(iii) Unchanged 1

(iv) Increased 1
Equilibrium IO_3^-/I_2 displaced to the right 1

Electrons more readily accepted or more reduction occurs or electrode becomes more positive (Q o L) 1

(c) VO_2^+ 1
5 or V 1
$V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ \ 3e^-$ 1

[12]

5. (a) Oxidising agents take/remove/accept/gain electrons **(1)**

Not 'electron pair' 1

(b) (i) Cl_2(g) at 100 kPa / 1 bar / 1atm **(1)**
$[Cl^-]$ = 1 molar / 1M **(1)**

Allow 1M HCl

Temperature = 298K / 25°C **(1)**

Do not use list principle for other incorrect species

(ii) Lower $[Cl^-]$ or reduce temperature
Increase pressure or concentration of Cl_2 **(1)**

CE if change incorrect

Equilibrium displace to right **(1)**

or if reduced temperature given, reaction exothermic

Allow a correct explanation when no change given 5

(c) (i) Cl^- **(1)**

(ii) Fe^{3+}; **(1)** NO_3^- **(1)**

Penalise by list principle

Note: H^+ is incorrect

(iii) V^{2+}, **(1)** Fe^{2+} **(1)**

Penalise by list principle 5

[11]

6. (a) (Standard) hydrogen (electrode) **(1)** 1

(b) (i) To allow transfer of electrons / provide a reaction surface **(1)**

(ii) 298 K **(1)**
Both F^{3+} (aq) and Fe^{2+} (aq) have a concentration of 1 mol dm^{-3} **(1)** (QoL)
OR $[H^+]$ = 1 mol dm^{-3}
NOT zero current or 100 kPa

3

(c) +1.34 V **(1)**
$2\ MnO_4^- + 5\ H_2SO_3 \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-} + 3\ H_2O + 4\ H^+$
Correct species / order **(1)**
Balanced and cancelled **(1)**
Allow one for $2\ MnO_4^- + 5\ H_2SO_3 \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-}$

3

(d) (i) Ce^{4+} (aq) **(1)**

(ii) VO_2^+ (aq) **(1)**; Cl_2 **(1)**
Penalise additional answers to zero

3

(e) Pt | Fe^{2+} (aq), Fe^{3+} (aq) || Ce^{4+}(aq), Ce^{3+} (aq) | Pt
Correct species **(1)**
Correct order **(1)**
Deduct one mark for each error

2

[12]

7. (a) *Cell e.m.f.*: 1.93 (v) CE if negative value given **(1)**
Half equation: $Mg \rightarrow Mg^{2+} + 2\ e^-$ **(1)**
or $\rightleftharpoons$
Ignore state symbols
Mark on after an AE

2

(b) *Change in e.m.f.*: increases **(1)**
Mark on even if incorrect

Explanation: Equilibrium displaced to Mg^{2+} or to the left **(1)**
cell reaction or overall reaction goes to the right
Electrode is more negative or E decreases
or gives more electron
or forms more Mg^{2+} ions
Mark separately

3

(c) *Cell e.m.f.* : –0.84 (V) **(1)**

Explanation: Fe is giving electrons **or** forming Fe^{2+}
or reaction goes in the reverse direction **(1)**
Mark on after AE

2

N.B. In (a) and (c) mark on if no value given, but CE in both (a) and (c) if e.m.f. = 0

[7]

8. (a) (i) (standard) hydrogen (electrode) / hydrogen half cell **not** hydrogen cell **(1)**

reference electrode / electrode to which others are compared **(1)** 2

(ii) 0.00(V) / 0 / zero **(1)** 1

(b) (i) emf = –0. 14 –(–0.25)
= + 0.11 V / allow 0.11V **not** – 0.11V **(1)** 1

(ii) electrode D / Sn^{2+} /Sn /tin / right hand electrode **(1)** 1

(iii) $Ni + Sn^{2+} \rightarrow Ni^{2+} + Sn$ (ignore state symbols) **(1)** 1

(c) (i) e.m.f = –0.44 – (–0.14) = –0.30 (V) / emf for cell is – ve
comparison of standard electrode potentials **(1)**

+ve e.m.f for feasible reaction / tin is a weaker reducing agent
$\therefore$ would not occur **(1)**

if correct ΔG argument used, allow both marks 2

(ii) manganese will decrease in size / disappear / eaten away / dissolves / solution turns (pale) pink **(1)**

effervescence / bubbles (of colourless gas) / fizzing **not** gas given off **(1)**

reaction likely to occur is $Mn + (2)H^+ \rightarrow Mn^{2+} + H_2$ **(1)**
or the same ideas expressed in words

+ve e.m.f. / +1.18 V / Mn is strong reducing agent / has large – ve $E^{\ominus}$ **(1)**
(**not** just Mn is more reactive) 4

[12]

9. (a) oxidising agent <u>accepts</u> electrons **(1)** 1

(b) *Stronger oxidising agent* H^+ **(1)**

Equation

$$H^+(aq) + e^- \rightarrow \tfrac{1}{2}H_2(g)$$
$$D^+(aq) + e^- \rightarrow \tfrac{1}{2}D_2(g)$$
$$H^+(aq) + \tfrac{1}{2}D_2(g) \rightarrow D^+(aq) + \tfrac{1}{2}H_2(g)$$ **(1)**

e.m.f. 0.000 – (–0.004) = + 0.004 V **(1)** 3

(c) *Equation* $AgF(s) + Cl^-(aq) \rightarrow AgCl(s) + F^-(aq)$ **(1)**
e.m.f. = + 0.78 – 0.22 = +0.56 V **(1)** 2

(d) (i) Silver lies above hydrogen in the electrochemical series
Or $Ag^+(aq)$ is a stronger oxidising agent than $H^+(aq)$ **(1)**

(ii) *Hydrogen halide* HI **(1)**

Equation $H^+(aq) + I^-(aq) + Ag(s) \rightarrow AgI(s) + \tfrac{1}{2}H_2(g)$ **(1)**
e.m.f. 40.00 – (–0.15) = + 0.15 V **(1)** 4

[10]

10. (a) *Reducing agent* Br_2 **(1)**

Half equation $Br_2 + 6H_2O \rightarrow 2BrO_3^- + 12H^+ + 10e^-$ **(1)** 2

(b) (i) *Temperature* 298 K or 25°C **(1)**

Concentration 1.00 M or 1.00 mol dm^{-3} **(1)**

(ii) *Secondary standard electrode* calomel
or Ag/AgCl **(1)**

Reason Easier to use
or hydrogen electrode **(1)**
difficult to use 4

(c) (i) $[Co(H_2O)_6]^{3+}$ **(1)**

(ii) $[Co(H_2O)_6]^{2+}$ **(1)**

(iii) $E^{\ominus}$ for $[Co(CN)_6]^{3-}/[Co(CN)_6]^{4-}$ is negative with respect to H^+/H_2 **(1)**
Electrons flow to H^+/H_2 and H^+ reduced **(1)** 4

[10]

11. (a) $Fe + Cu^{2+} \rightarrow Cu + Fe^{2+}$ **(1)**

allow use of soluble Cu salt eg $CuSO_4$
ignore state symbols 1

(b) (i) $Fe(s) \mid Fe^{2+}(aq) \,\|\, Cu^{2+}(aq) \mid Cu(s)$

junctions correct **(1)**
ignore state symbols
allow alternative symbols for salt bridge
allow if junctions are correct but order is wrong providing
metals on each side of salt bridge are the same ie Fe | Fe^{2+} not Fe | Cu^{2+}

order of species correct **(1)**
do not give this mark if cell reversed 2

(ii) e.m.f. = + 0.34 – (–0.44)
= + 0.78 V **(1)**
must have + sign
allow – 0.78 (V) if reverse cell given in (i) 1

(c) (i) e.m.f for cell must be positive for reaction to occur / be feasible / **(1)**
spontaneous **or** ΔG must be negative)

$Cu(s) + 2H^+ \rightarrow$ products
e.m.f = – 0.34 ∴ won't happen /
sensible comparison of the magnitude of $E^{\ominus}$ for the electrodes
eg 'Cu electrode more positive than hydrogen electrode ∴ won't work' **(1)**

$Cu(s) + NO_3^- + 4H^+ \rightarrow$ products
e.m.f = + 0.96 – 0.34 = +0.62 ∴ can occur /
similar sensible comparison **(1)** 3

(ii) $3Cu + 2\,NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

species **(1)**
balanced – this mark dependent on first mark **(1)** 2

(d) (i) $2Fe + O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4OH^-$ **or** $2Fe(OH)_2$ **(1)**
ignore state symbols 1

(ii) anode (only give this mark if explanation attempted) **(1)**

Fe loses e^- (∴ negative pole) / oxidation occurs **(1)**
this mark dependent on anode for first mark 2

(iii) e.m.f. = + 0.06 V or reference to $E^{\ominus}$ for electrodes **(1)**

reasoned argument **(1)**
eg positive ∴ should occur / difference so small that reaction unlikely 2

[14]

12. (a) *Name* hydrogen electrode **(1)**

Conditions 1 M $H^+(aq)$ or 1 M HCl(aq) or 0.5 M $H_2SO_4(aq)$ **(1)**
298 K **(1)**
Hydrogen gas at 1 bar or 100 kPa **(1)** 4

(b) (i) $E^{\ominus}$ *value* 1.21 v **(1)**

Equation $S_2O_8^{2-} + 2Ag \rightarrow 2SO_4^{2-} + 2Ag^+$ **[2]**

(ii) *Change, if any, in electrode potential* Less positive or decrease **(1)**

Explanation Equilibrium displaced to the left **(1)**
More electrons released **(1)** 6

[10]

13. (i) Oxidising agents

$Cu^{2+}(aq)$ **(1)**, $H_2O_2(aq)$ **(1)**, $C1_2(aq)$ **(1) (3)**
if $Cr_2O_7^{2-}(aq)$ is included, deduct one mark

(ii) $2I^- \rightarrow I_2$ $I(-1) \rightarrow I(0)$ **(1)**

$Mn^{2+} \rightarrow MnO_4^-$ $Mn(II) \rightarrow Mn(VII)$ **(1)**

$Cr_2O_7^{2-} \rightarrow 2CrO_4^-$ no change (penalised above)

$Cl_2 \rightarrow ClO^-$ $Cl(0) \rightarrow Cl(1)$ **(1)**

(iii) $Cu^2(aq) + I^-(aq) + e^- \rightarrow Cu^+(s)$ **(1)**

$I^-(aq) \rightarrow ½ I_2(aq) + e^-$ (not reverse) **(1)**

$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O$ **(1) (1)**

$Mn^{2+}(aq) + 4H_2O$ **(1)** $\rightarrow MnO_4^-(aq) + 8H^+(aq) + 5e^-$ (not reverse) **(1)**

$\frac{1}{2} Cl_2(aq) + e^- \rightarrow Cl^-(aq)$ **(1)**

$½ Cl_2(aq) + 2OH^-(aq) \rightarrow ClO^-(aq) + H_2O(l) + e^-$ (not reverse) **(1)**

Penalise missing or incorrect state symbols once only
(12 MAX)

11

[11]