Mark Scheme - 3.8 Equilibrium Constants

1.

The position of equilibrium moves to the right / more COS is formed (1)
(By Le Chatelier's principle) the system 'removes' added 'material' to restore the position of equilibrium / accept explanation in terms of pressure (1) [2]

2. Acid: Proton donor (1)

Dynamic equilibrium: Reversible reaction where the **rate** of forward and reverse reactions is equal (1) [2]

3.

(a) Name of any commercially/ industrially important chlorine containing compound e.g. (sodium) chlorate(I) as bleach/ (sodium) chlorate(V) as weedkiller/ aluminium chloride as catalyst in halogenation
- do not accept CFCs **[1]**

(b) (i) $K_c = \frac{[HI]^2}{[H_2][I_2]}$ must be square brackets **[1]**

(ii) $K_c = \frac{0.11^2}{3.11^2} = 1.25 \times 10^{-3}$ follow through error (ft) **[1]**

(iii) K_c has no units ft **[1]**

(iv) when temperature increases K_c increases (1)

this means equilibrium has moved to RHS
/ increasing temperature favours endothermic reaction (1)

therefore ΔH for forward reaction is +ve (1)
(mark only awarded if marking point 2 given) **[3]**

(c) (i) +2 **[1]**

(ii) co-ordinate/ dative (covalent) **[1]**

(iii) pink is $[Co(H_2O)_6]^{2+}$ **and** blue is $[CoCl_4]^{2-}$ (1)

(ligand is) Cl^- (1)

(addition of HCl sends) equilibrium to RHS (1) **[3]**

(iv) $[Co(H_2O)_6]^{2+}$ shown as octahedral [with attempt at 3D] (1)

$[CoCl_4]^{2-}$ shown as tetrahedral/ square planar (1) **[2]**

Total [14]

4.

(a) Benefits:
Stops fossil fuels from running out
Reduces CO_2 emissions / greenhouse emissions / global warming / effect of global warming
Reduces SO_2 emissions / acid rain
There will be an investment in new technology

Difficulties:
Dependence on fossil fuel/Unlikely to meet current demand
Renewable energy currently more expensive
Reliability of supply from renewables
Major development in energy efficiency technologies required
Opposition by vested interests
(Maximum 3 marks from list, but need examples of both) (3)

Consideration and discussion of benefits/difficulties (1) [4]

QWC Legibility of text; accuracy of spelling, punctuation and grammar, clarity of meaning [1]

(b) (i) I As temperature increases yield decreases
As pressure increases yield decreases [1]

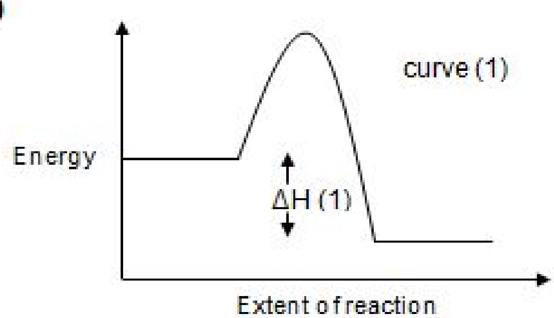
II As temperature is increased, equilibrium moves to the left (1)
Therefore forward reaction is exothermic (1)
As pressure is increased, equilibrium moves to the left (1)
Therefore more gas moles in products (1) [4]
QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(ii) If temperature is too low, then reaction is too slow (1)
If temperature is too high, yield is too low (1)
Compromise temperature – acceptable rate and yield (1)
(Accept any two points) [2]

(iii) Heterogenous catalyst [1]

(iv) Lower temperatures could be used (1)
Less energy consumption / increased yield (1)
Equilibrium could be reached more quickly (1)
(Accept any two points) [2]

(v)



[2]

(vi) $\Delta H = E_f - E_b$ [1]

Total [19]

5.

(a) Low temperature (1)
As temperature is decreased equilibrium moves in exothermic direction. (1)

High pressure (1)

As pressure is increased equilibrium moves towards side with smaller number of gas moles (1) [4]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(b) ΔHreaction = ΔH_f products – ΔH_f reactants (1)

-46 = ΔH_f ethanol – (52.3 – 242)

ΔH_f ethanol = -46 – 189.7 (1)

ΔH_f ethanol = -235.7 kJ mol^{-1} (1) [3]

(c) Bonds broken = 1648 + 612 + 926 = 3186 kJ mol^{-1} (1)

Bonds formed = 2060 + 348 + 360 + 463 = 3231 kJ mol^{-1} (1)

ΔH reaction = 3186 – 3231 = -45 kJ mol^{-1} (1)

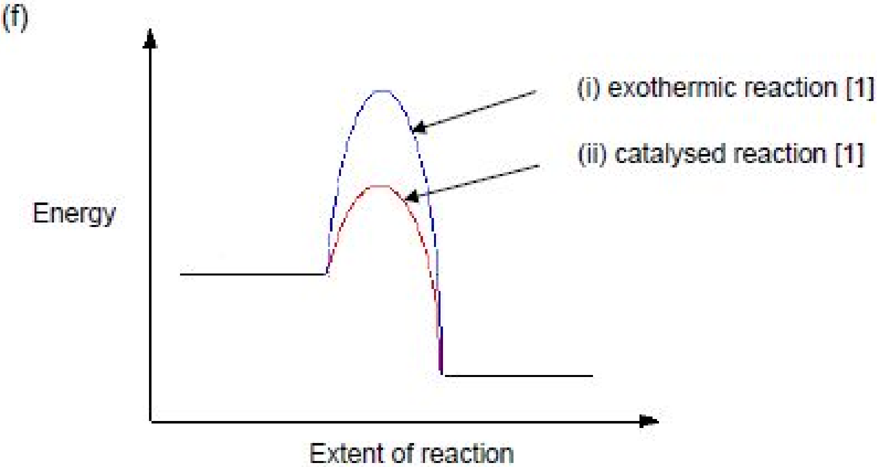
[3]

(d) (i) Average bond enthalpies used (not actual ones) [1]

(ii) Yes, since answers are close to each other [1]

(e) Catalyst is in different (physical) state to reactants [1]

(f)



Total [16]

6.

(a)	(i)	Temperature: 298K / 25°C (1) Pressure: 1 atm / 101.325 kPa or 100 kPa (1)	[2]
	(ii)	Hydrogen gas is an element in its standard state	[1]
	(iii)	$\Delta H = \Delta H_f\,(C_5H_{12}) + 5\,\Delta H_f\,(H_2O) - 5\,\Delta H_f\,(CO) - 11\Delta H_f\,(H_2)$ (1)	
		$\Delta H_f\,(C_5H_{12}) = -1049 - 5\,(-286) + 5\,(-111)$ (1)	
		$\Delta H_f\,(C_5H_{12}) = -174\ kJ\ mol^{-1}$ (1)	[3]
(b)	(i)	Catalyst in different state to reactants	[1]
	(ii)	Catalysts provide an alternative route (1) with a lower activation energy (1)	[2]
	(iii)	Lower temperature or less time so less energy needed / Can make alternative production method possible with sustainable starting materials or less waste products	[1]
	(iv)	At higher temperatures particles have more energy (1)	
		More collisions have energy above activation energy (1)	
		(Can obtain these two marks from correctly labelled Boltzmann energy distribution plot with two temperature lines (1) and Activation energy (1))	
		Successful collisions occur more frequently (1) – 3 max	[3]
		QWC: selection of a form and style of writing appropriate to purpose and to complexity of subject matter	[1]
(c)	(i)	No effect (1)	
		Same number of (gas) molecules on both sides of reaction (1)	[2]
	(ii)	Lower yield of hydrogen (1)	
		Reaction shifts in endothermic direction to (try to counteract increase in temperature) (1)	[2]
	(iii)	No effect	[1]

Total [19]

7.

(a)	killing marine life / killing trees			[1]
(b)	(i)	either gas syringe or inverted burette attached to sealed vessel		[1]
	(ii)	different surface area would affect rate of reaction		[1]
	(iii)	concentration / volume / nature of acid (1)		
		temperature (1)		[2]
(c)	(i)	increasing pressure will shift the reaction to side with fewer gas molecules (1)		
		increasing yield of SO_3 (1) – reason must be given		[2]
	(ii)	I	increasing temperature shifts equilibrium in endothermic direction (1)	
			as SO_3 yield is decreased forward reaction must be exothermic (1)	[2]
		II	increasing temperature increases energy of particles (1)	
			more collisions have energy above activation energy (1)	
			successful collisions occur more frequently (1)	
			can gain first two points from labelled Boltzmann distribution curve	[3]
		III	e.g. iron in production of ammonia or any valid example	[1]
(d)	(i)	atom economy = 100%		[1]
	(ii)	any two points from:		
		lower pressure used in B (1)		
		methanol is a renewable starting material (1)		
		higher atom economy in B or less waste in B (1)		
		[ignore reference to cost] 2 max		[2]
	(iii)	no effect on position of equilibrium		[1]

Total [17]

8.

(a) - 705 (kJ mol^{-1}) (1) for correct sign (1) for correct number [2]

(b) (i) ……………………………….. hydration ……………………

……………………….. lattice **breaking** [1]

(ii) e.g. add a small 'amount' of an alkali / sodium hydroxide / NaOH / OH^- ions (1)
this would remove / react with hydrogen ions giving water, shifting the position of equilibrium to the left (removing iodine) (1)
add $P6^{2+}$ / Ag^+ ect. [2]

(c) (i) Any TWO from
white / misty fumes (of HI)
yellow solid / solution (of sulfur)
brown / black solid / purple vapour (of iodine)
bubbles / effervescence / fizzing

One mark for each correct response [2]

(ii) The values show that chlorine is the best oxidising agent, as it has the most positive E^θ value and therefore iodide is the better reducing agent (1)
and is 'strong' enough to reduce the sulfuric acid. / OWTTE (1) [2]

(d) (i) $2\,NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$ [1]

(ii) e.g. bleach, kills bacteria [1]

Total [11]

9.

(a) (a reaction in which) the rate of the forward reaction is equal to the rate of the backward reaction [1]

(b) goes darker / more brown (1)

because the (forward) reaction has a +ve ΔH / is endothermic (1)

goes paler / less brown (1)

because there are more moles / molecules on RHS (1)

no change (because catalysts do not affect the position of an equilibrium) (1) [5]

(c) (i) moles N_2H_4 = 14000/32.04 = 437.0 (1)

this produces 437.0 × 3 = 1311 moles of gas (1)

volume = 1311 × 24 = 3.15×10^4 dm^3 (1) [minimum 2 sf] [3]

(ii) (large volume of) gas produced [1]

(d) (i) an acid is a proton / H^+ donor [1]

(ii) $\rightarrow NO_2^- + H_3O^+$ [1]

(iii) sulfuric acid is behaving as the acid / nitric acid is behaving as a base (1)

as it donates a proton / as it accepts a proton (1) [2]

Total [14]