Question number				Answer	Notes	Marks
1	a	i	M1	air / atmosphere		1
			M2	water / natural gas / hydrocarbons	Allow methane	1
		ii	M1	iron / Fe	Ignore iron oxide Accept phonetic spellings Do not penalise other included numbers - eg Fe(II) / Fe(III) / Fe^{2+} / Fe^{3+}	1
		iii	M1	450 ºC	Accept temperature of 350ºC to 550ºC or temperatures in K If range given, both values must be within acceptable range	1
			M2	200 atm(ospheres)	Accept pressure of 150 atm to 250 atm or pressures in Pa Unit needed for mark If two conditions given, both must be correct	
		iv	M1	cooled / temperature lowered		1
			M2	ammonia liquefies / condenses	M1 and M2 are independent Do not award M2 if implication that other gases condense	1

Question number				Answer	Notes	Marks
1	b		M1	$n(N_2) = (56 \times 10^6) \div 28$ / 2×10^6	No penalty for missing or incorrect power of 10	1
			M2	$n(NH_3) = M1 \times 2$ / 4×10^6	Conseq on M1	1
			M3	$m(NH_3) = M2 \times 17$ / 68 t(onnes)	Conseq on M2 Correct final answer with units scores 3 Accept answers in grams and kilograms 34 t scores 2 marks Final answer of 68 with missing or incorrect units scores 2	1
				OR $\dfrac{34 \times 56}{28}$ = 68 t(onnes)	M1 for 28 and 34 (need not be in this expression) M2 is for expression shown M3 is for answer with units	
	c	(i)	M1	increased		1
			M2	shift to left	Allow less ammonia / products Allow moves in reverse direction Ignore reference to favouring	1
		(ii)	M1	shift to right	Allow more ammonia / products Allow moves in forward direction Ignore reference to favouring	1
			M2	fewer moles/molecules (of gas) on the right	Allow more moles/molecules on the left Do not penalise incorrect numbers, eg 3 moles on the left and 2 moles on the right Ignore references to rate M2 dependent on M1	1

Question number				Answer	Notes	Marks
1	d	i	M1	60		1
		ii	M1	setting out correct division of each % by A_r OR 2.5, 5 and 3.75	Award 0 for whole question if division by atomic numbers / wrong way up / multiplication used If molecular masses used for all three elements, no M1, but can award M2 and M3	1
			M2	division by smallest (gives 1 : 2 : 1.5)	No penalty for subsequently rounding 1.5 to 2 if clear they have divided by smallest	1
			M3	$N_2H_4O_3$	Accept elements in any order Allow NH_4NO_3 If % O wrong or missing, only M1 and M2 can score	1
		iii	M1	ammonium nitrate	Accept phonetic spellings Do not accept ammonia in place of ammonium Do not accept nitrite or nitride in place of nitrate Ignore all formulae	1

Total 18 marks

Question number				Answer	Notes	Marks
2	a		M1	(total) volume different/not constant / not 50 / is 55	Allow too much water / sodium thiosulfate added / reference to numbers eg should be 10 instead of 15 or 35 instead of 40	1
	b		M1 M2 M3	All six points plotted correctly to nearest gridline <u>curve</u> of best fit	Deduct 1 mark for each error If plotting cannot be seen judge accuracy from the line. Do not award mark for joining dots or multiple lines or if all of the data points are completely misplotted	2 1
	c		M1 M2	1000 ÷ 26.6 37.6	 Ignore units M2 can be awarded for use of another student's result Award 2 marks for correct final answer Award 1 mark for 38 / 37.59 / 37.5	1 1

Question number				Answer	Notes	Marks
2	d	i	M1 M2	rate (directly) proportional to concentration	Accept concentration (directly) proportional to rate Accept specific quantitative expression, eg rate doubles as concentration doubles Allow 1 mark for qualitative expression, rate increases as concentration increases	2
2	d	ii	M1 M2 M3	more particles / ions (in a given volume) collide (successfully) more frequently	Reject atoms / molecules Reject with more energy Ignore greater chance of collision Must be reference to frequency or number of collisions per unit time Allow "increased frequency of collisions" for M2 and M3	1 1 1

Total 11 marks

Question number	Answer	Notes	Marks
3 a i	(pressure) low		1
ii	fewer (gas) moles/molecules/particles on left OR fewer moles/molecules/particles of reactants OR forward reaction produces more moles/molecules/particles	Accept statement about numbers of moles / molecules, eg 3 on left and 5 on right Accept more (gas) moles/molecules/particles on right / more moles/molecules of products but not just more products Ignore references to favouring right hand side/forward direction /endothermic reaction /equilibrium shifting to right /Le Chatelier's principle /low pressure favours side with more moles Ignore references to rate / collisions If answer to (i) is high, no ECF in (ii) If no answer to (i), mark can be awarded in (ii)	1
b i	(temperature) high		1
ii	(forward) reaction is endothermic / has positive ΔH value / absorbs heat	Accept reverse reaction is exothermic / has negative ΔH value / gives out heat Ignore favours the endothermic reaction Ignore references to rate / collisions If answer to (i) is low, no ECF in (ii) If no answer to (i), mark can be awarded	1

c	ΔH (value)/enthalpy change is small / smaller / less (than for reactions 1 and 3) OR reaction not very exothermic / has lowest enthalpy change	Accept energy in place of enthalpy Accept clos<u>er</u> to zero Reject ΔH less negative / less exothermic / less heat given out Ignore references to temperature change / pressure Ignore less energy / not a lot of energy needed	1

Question number	Answer	Notes	Marks
3 d		Ignore references to yield / equilibrium / chances of collision in (i) d (ii)	
i	(rate) increases		1
ii		Mark M1 and M2 independently	2
	M1 particles closer together	Accept more particles in a given volume/space /particles have less space/room (to move in) Ignore area in place of volume/space Ignore references to just numbers of gas moles/molecules	
	M2 particles collide more frequently	Not just more (successful) collisions Accept more (successful) collisions per unit time / per second, etc 0/2 if references to particles moving faster/having greater energy If answer to (i) is decreases, no ECF in (ii) If no answer or ignored answer to (i), marks can be awarded	

Question number	Answer	Notes	Marks
3 e	Accept working by mass ratio OR moles routes Mass ratios: M1 M_r (CH_3OH) = 32 AND M_r (CH_3COOH) = 60 M2 m($_3$COOH) = $\frac{64 \times 60}{32}$ M3 120 (kg) OR Moles: M1 n($_3$OH) = 64 000 ÷ 32 = 2000 (mol) M2 n($_3$COOH) = 2000 (mol) M3 m(CH_3COOH) 0 × = 120 0 0 g / 1 0 (kg)	Award M1 for 32 and 60 seen anywhere, except as the result of incorrect calculations Mark M2 and M3 consequentially on M_r values Allow working in 'kilomoles' even if mol given as unit or no unit for intermediate answers, eg 64 ÷ 32 = 2 (kmol/mol) CQ on M1 CQ on M2 Correct final answer with or without working scores 3 marks Accept 120 000 g if unit shown	3
		Total 11 marks	

Question number				Answer	Notes	Marks
4	a	i	M1	reversible (reaction) / goes forwards and/or backwards / can go in either direction	Ignore equilibrium	1
			M2	enthalpy/heat/energy change	Ignore kJ/mol Reject energy produced/released	1
		ii		exothermic / heat/energy given out/lost	Accept enthalpy in place of heat/energy Ignore references to temperature	1
	b		M1	two (vaguely) horizontal lines: one with reactants or their formulae AND one with products or their formulae	Ignore all curves and connecting lines Ignore line representing *x*-axis and any label Accept R for reactants and P for products	1
			M2	reactants (line) above products (line)	No penalty for products to left of reactants	1
					Accept formulae in place of words for reactants and products Do not penalise minor errors in formulae (e.g. NH instead of NH_3) or missing coefficients	
	c		M1	(effect of temp on rate) increased		1
			M2	(effect of temp on yield) decreased		1
			M3	(effect of catalyst on rate) increased		1
			M4	(effect of catalyst on yield) unchanged		1

Question number				Answer	Notes	Marks
4	d	i	M1	decreased	No ECF from increased / no effect Accept longer time for reaction Ignore references to equilibrium	1
			M2	particles further apart/more widely spaced / more space to move in / concentration decreases	Accept molecules Reject atoms/ions in M2 only If neither of M2 and M3 scored, accept fewer collisions with no reference to frequency or time	1
			M3	less frequent (successful) collisions / fewer (successful) collisions per second/minute	Accept more time between collisions Ignore decreased chance / probability / likelihood of collisions	1
					References to change in energy/speed of particles means M2 and M3 cannot be scored	
		ii	M1	shifted to right / more products / shifts in exothermic/forward direction	Ignore references to rate No ECF from shift to left / no change Accept forward reaction favoured	1
			M2	more (gas) moles/molecules on right	Accept fewer (gas) moles on left Accept favours side with more (gas) moles Accept 9 moles on left and 10 moles on right	1
	e			4 ( ) 2 4	Accept fractions and multiples	1
					Total	15