

Question	Answer	Marks	AO Element	Notes	Guidance
1	D - $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + 5\text{H}_2\text{O}$	1			
2	A - Carbon monoxide is oxidised to carbon dioxide.	1			
3(a)	4.76 (dm ³)	1			
3(b)	moves equilibrium to right	1			
	increases yield (of sulfur trioxide) / uses up more sulfur dioxide	1			
3(c)(i)	moves equilibrium to left	1			
	(forward reaction) exothermic	1			
3(c)(ii)	decreases rate	1			
	molecules have less energy / move slower	1			
	fewer collisions (per second) / fewer particles have the activation energy / fewer collisions have the activation energy	1			

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3(d)(i)	moves to right	1			
3(d)(ii)	high yield at 2 atm	1			
4	reversible (reaction) / equilibrium (reaction)	1			
5	reversible reaction / equilibrium	1			
6	reversible reaction	1			
7	reversible reaction	1			
8	28%	1			
9(a)	2 (Fe) (1) 3 (Cl ₂) (1)	2			
9(b)	reversible reaction	1			
10(a)	carbon dioxide	1			

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10(b)	anhydrous copper(II) sulfate / white copper(II) sulfate (1) turns blue (1) OR anhydrous cobalt(II) chloride / blue cobalt(II) chloride (1) turns pink / red (1)	2			
11	B	1			
12(a)	reversible reaction	1			
12(b)	heat / warm	1			
13	3 (H ₂) (1) ⇌ (1) 2 (UH ₃) (1)	3			
14(a)	(symbol for reversible reaction) ⇌	1			
14(b)	add water	1			

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15	colourless liquid collects / condenses at top of the tube (1) copper(II) sulfate turns white (1)	2			
16(a)	reversible reaction	1			
16(b)	blue	1			
	pink	1			
17	decreases as the temperature increases ORA	1			
18(a)	condensation (at mouth of tube)	1			
18(b)	add (aqueous) sodium hydroxide / (aqueous) ammonia (1) green precipitate (1)	2			

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19(a)	<p>reversible reaction in which the rate of the forward reaction equals the rate of the backward reaction (1)</p> <p>concentration of all reactants and products becomes constant / does not change (1)</p>	2			
19(b)	<p>forward reaction is endothermic (1)</p> <p>(increased temperature) causes equilibrium to shift to the right / to shift in the endothermic direction / to form more nitrogen dioxide / to form more product(s) (1)</p>	2			
19(c)	<p>less brown / lighter / paler / colour fades (1)</p> <p>more molecules / moles / volume on the right ORA</p> <p>OR</p> <p>equilibrium shifts in the direction of fewer molecules / moles / lower volume (1)</p>	2			
20(a)	<p>white (1)</p> <p>to blue (1)</p>	2			

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20(b)	it has (two different types of) atoms bonded / joined	1			
21	D - The colour change observed when water is added to anhydrous cobalt(II) chloride is from pink to blue.	1			
22	\rightleftharpoons ;	1			
	6H ₂ O on right;	1			
23(a)	\rightleftharpoons	1			
23(b)	pressure 100–300 atmospheres / atm (1) temperature in range 330 to 500 °C (1) iron (catalyst) (1) species: N ₂ + 3H ₂ \rightleftharpoons 2NH ₃ (1) fully correctly equation (1)	5			
23(c)	water / steam or methane / natural gas	1			

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24(a)	moves right (1) fewer moles / molecules (of gas) on right (1)	2			
24(b)	(reaction is faster) because more collisions per second (1) particles / molecules closer together or more particles / molecules per unit volume (1)	2			
24(c)	moves left (1) (forward) reaction is exothermic or backward reaction is endothermic (1)	2			
25	fewer OR less molecules OR moles + on right OR in product (1) ORA equilibrium shifts to the right (1)	2			
26(a)	M1 less ester M2 equilibrium moves left AND because forward reaction is exothermic	2			

Question	Answer	Marks	AO Element	Notes	Guidance								
26(b)	M1 more ester M2 (equilibrium moves right) to replace water	2											
27(a)	water / natural gas / hydrocarbons	1											
27(b)	<table border="1"> <tr> <td>effect on the rate of the reverse reaction</td> <td>effect on the equilibrium yield of CH₃OH(g)</td> </tr> <tr> <td>M1 increases</td> <td></td> </tr> <tr> <td></td> <td>M3 decreases</td> </tr> <tr> <td>M2 decreases</td> <td>M4 decreases</td> </tr> </table>	effect on the rate of the reverse reaction	effect on the equilibrium yield of CH ₃ OH(g)	M1 increases			M3 decreases	M2 decreases	M4 decreases	4			
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29	forward and back reactions occur at equal rates (1) concentration (of substances) remains constant (1)	2											

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30(a)	equal / same number of moles on each side or amount / molecules (of gas) on each side is the same	1			
30(b)	(forward) reaction exothermic or reverse reaction endothermic yield lower at higher temperature or (position of) equilibrium moves left at higher temperature ORA	2			
31(a)	$2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$ M1 Balanced equation M2 reversible arrow	2			
31(b)	450 °C (units required) (1) 1–5 atmospheres (units required) (1) vanadium(V) oxide or vanadium pentoxide or V_2O_5 (1)	3			A 723 K A 100–500 kPa
31(c)	SO_3 added to (concentrated) H_2SO_4 (1) (oleum) diluted with / added to water (1)	2			

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32	the rate of forward reaction equals (the rate of the) reverse reaction (1) concentrations of reactants and products are constant (1)	2			
33(a)	becomes pink / becomes purple (1) equilibrium moves right (1)	2			
33(b)	(forward reaction is) exothermic	1			
34(a)	to left / towards reactants / in reverse direction	1			
34(b)	increase / faster (1) increase / faster (1)	2			
35(a)	same number of gas moles on both sides of the equilibrium / same number of gas molecules on both sides of the equilibrium	1			
35(b)	(increased pressure) particles or molecules (forced) closer together / same number of particles or molecules in a smaller volume	1			

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36(a)	becomes paler (1) equilibrium moves right (1) (because) fewer moles (of gas) on right (1)	3			
36(b)	equilibrium moved right / more N_2O_4 / less NO_2 (1) (forward) reaction exothermic (1)	2			
37(a)	210 cm^3 M1 expected volume of hydrogen = 300 cm^3 M2 70% of M1	2			
37(b)	fewer moles / molecules / particles (of gas) on the left-hand side	1			
37(c)	endothermic	1			
37(d)	increases rate (of reaction)	1			

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38(a)	colours referred to correctly as observations AND (if sulfuric acid is added to solution Y ,) equilibrium moves to the right-hand side (1) because the concentration of acid has increased (1)	2			
38(b)	colours referred to correctly as observations AND (if sodium hydroxide is added to solution Y ,) equilibrium moves to the left-hand side (1) because sodium hydroxide reacts with / neutralises sulfuric acid (1)	3			
39	B	1			
40	B - increasing the pressure	1			
					[Total: 119]