

Question	Answer	Marks	AO Element	Notes	Guidance
1(a)	4.76 (dm ³)	1			
1(b)	moves equilibrium to right	1			
	increases yield (of sulfur trioxide) / uses up more sulfur dioxide	1			
1(c)(i)	moves equilibrium to left	1			
	(forward reaction) exothermic	1			
1(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			
1(d)(i)	moves to right	1			
1(d)(ii)	high yield at 2 atm	1			
2	M1 dissolve / react sulfur trioxide in (concentrated) sulfuric acid	1			

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	add water to product of M1	1			
3	vanadium(V) oxide / vanadium pentoxide	1			
4	calcium carbonate	1			
	carbon dioxide	1			
5	food preservative / manufacture of wood pulp	1			
6	underground / named geographical source, e.g. Poland / Louisiana / Sicily	1			
7	sulfur dioxide	1			
8	SO ₂ / sulfur dioxide	1			
9	V ₂ O ₅ / vanadium(V) oxide	1			
10	sulfur / S	1			
11	sulfur dioxide	1			

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12	C - It reacts with ammonia to produce a fertiliser.	1			
13	<i>source:</i> underground / volcanoes / crude oil / petroleum (1) <i>use:</i> e.g. (making) sulfuric acid / making SO ₂ / dusting plants / vulcanising rubber (1)	2			
14	C	1			
15	A - A catalyst of iron is used.	1			
16(a)	sulfuric acid	1			
16(b)	(chemical) erosion (of buildings) / pitting (of buildings) / corrosion (of metalwork) / weathering	1			
16(c)	sulfur dioxide gains oxygen / it gains oxygen	1			
17	D	1			
18	D	1			
19	A - It is a dehydrating agent.	1			

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20	water absorbed	1			
21(a)	speeds up reaction	1			
21(b)	O ₂ (on left)	1			
	correct balance (2 on right)	1		note: second mark dependent on O ₂ or 2O on left	
21(c)	to prevent it turning into liquid / vapour	1		allow: so temperature is below melting point / so that it can form crystals	
22	(the reaction is) too violent/too exothermic or produces mist/fumes (of acid)	1			
23	Any two from: bleach/making wood pulp/making paper food/fruit juice/wine preservative fumigant/sterilising/insecticide	2			
24	heating/roasting/burning (zinc sulfides)	1			
	in air/oxygen	1		COND on M1	

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25	making fertilisers or pickling metals or making fibres or making phosphoric acid/phosphates making dyes or making paints/pigments/dyes or making paper or making plastics or making detergents or tanning leather or battery acid.	1			
26(a)	l...g...g.	1			
26(b)	vanadium(V) oxide or vanadium pentoxide (1) 450 (°C) (1)	2			
26(c)	$\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_7$ (1) $\text{H}_2\text{S}_2\text{O}_7 + \text{H}_2\text{O} \rightarrow 2\text{H}_2\text{SO}_4$ (1)	2			
27(a)	proton acceptor	1			
27(b)	Contact (process)	1			
27(c)	$2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$ $(\text{NH}_4)_2\text{SO}_4$ (1) rest of the equation (1)	2			

Question	Answer	Marks	AO Element	Notes	Guidance
28(a)	water / H ₂ O	1			
28(b)	carbon / C	1			
29(a)	from petroleum or (crude) oil or fossil fuels	1			
29(b)	Contact (process)	1			
29(c)	vanadium pentoxide or vanadium(V) oxide or V ₂ O ₅ (catalyst); (1) 1–5 atmospheres; (units required) (1) 450°C; (units required) (1) 2SO ₂ + O ₂ → 2SO ₃ ; (1) equilibrium / reversible reaction in equation or text (1)	5			
30(a)	2SO ₂ + O ₂ ⇌ 2SO ₃ M1 Balanced equation M2 reversible arrow	2			

Question	Answer	Marks	AO Element	Notes	Guidance
30(b)	450 °C (units required) (1) 1–5 atmospheres (units required) (1) vanadium(V) oxide or vanadium pentoxide or V ₂ O ₅ (1)	3			A 723 K A 100–500 kPa
30(c)	SO ₃ added to (concentrated) H ₂ SO ₄ (1) (oleum) diluted with / added to water (1)	2			
31(a)	V ₂ O ₅	1			
31(b)	position of equilibrium shifts right/yield increases	1			
	to save energy	1			
31(c)	faster reaction/rate	1			
	more collisions per second/higher collision frequency	1			
	fewer moles/molecules (of gas) on right	1			

Question	Answer	Marks	AO Element	Notes	Guidance
	(so) position of equilibrium shifts right/yield increases	1			
32(a)	$2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$ species (1) balancing (1)	2			
32(b)	Manufacture of sulfuric acid or bleach or making wood pulp or making paper or food or fruit juice or wine preservative or fumigant or sterilising	1			
33(a)	add water (to yellow solid or to (anhydrous) iron(II) sulfate or to FeSO_4 or to products	1			
	goes green	1			
33(b)	M1 Sulfur trioxide reacts with water to make sulfuric acid or equation	1			
	M2 sulfur dioxide reacts with oxygen to form sulfur trioxide or equation	1			

- Mark Scheme

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33(c)	M1 = 2.07	1		Allow 2.1 or 2.0666...7	
	M2 = 62.8.g	1			
	M3 (= M2/152 =) 0.41(3)	1			
	M4 (= M1/M3) rounded to the nearest whole number $\times = 5$	1			
					[Total: 87]