1. (a) when the conditions on a system in equilibrium are changed **(1)**
the equilibrium moves to minimise the effects of the change/
counteract/ resist/ oppose the change **(1)** 2

(b) (i) equilibrium moves towards LHS/ towards NO_2 **(1)**
forward reaction is exothermic/ reverse reaction is endothermic **(1)** 2

(ii) equilibrium moves towards RHS/ towards N_2O_4 **(1)**
fewer moles on RHS **(1)** 2

(iii) no change in equilibrium position **(1)**
catalyst speeds up forward ad reverse reactions by same amount **(1)** 2

[8]

2. (i) curve displaced to the right **(1)**
maximum is lower **(1)** 2

(ii) area under curve exceeding E_a = number of molecules that can react **(1)**
at higher temperature, area under curve > E_a is greater so more can react **(1)** 2

[4]

3. (a) (i) $MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$

balancing ✓
state symbols ✓ 2

(b) (as the reaction proceeds) the concentration decreases ✓
(rate) of collision decreases ✓
reaction stops when all of one reagent is used up ✓ 3

(c) (i) sketch to show slower rate of production ie less steep (must not be straight line) ✓
final volume the same but reached later ✓ 2

(ii) rate is slower
because
weak acid is partially ionised/ dissociated ✓
lower **concentration** of H^+ in weak/ higher **concentration** of H^+ in strong/ HC*l* ✓ 2

[9]

4. any two from
rate of forward reaction = **rate** reverse reaction ✓
macroscopic properties remain constant/ concentrations remain constant ✓
closed system needed ✓ 2

	(i)	a substance that alters the rate of a reaction without being used up / a substance that lowers the activation energy (for a reaction) by providing an alternative route ✓	1
	(ii)	catalyst is in the same state/ phase as reactants ✓	1
	(iii)	H^+ ✓	1
	(iv)	they alter the rate of the forward and the reverse reaction **by the same amount** ✓	1
			[6]

5.	(i)	axes labelled y as number/ fraction/ % of molecules/ particles and x as energy/ enthalpy/ velocity/ speed ✓ correct shape to include origin, hump and position wrt x axis ✓	2
	(ii)	two vertical lines **drawn** both to the RHS of hump (at least one labelled *Ea*) (labels reversed cannot score) ✓ greater proportion of collisions have energy greater than *Ea*/ more molecules exceed *Ea* ✓	2
			[4]

6.	(a)	pressure 50 – 1000 atm ✓ temperature 200 – 600°C ✓	2
	(b)	**rate** (increased) pressure increases rate because molecules are closer together/ more concentrated ✓ (increased) temperature increases rate because molecules are moving faster/ have more energy ✓ **equilibrium** increased pressure pushes equilibrium to RHS ✓ because fewer (gas) moles/ molecules on RHS ✓ increased temperature pushes equilibrium to LHS ✓ because (forward) reaction is exothermic ✓ **compromise** if temperature is **too** high, low yield ✓ if temperature is **too** low, slow rate ✓ if pressure is too high, increased costs/ safety issues ✓	9
			[11]

7. (a) when the conditions on a reaction in **equilibrium** are **changed/ disturbed** ✓
the (equilibrium) moves in the direction to minimise the effects of the change ✓ — 2

(b) (i) equilibrium moves to the LHS/ more X_2 and Y_2 are produced ✓
more moles (of gas)/ particles on LHS ✓ — 2

(ii) rate becomes less as there are less particles in a unit volume/ concentration less/ more space between particles ✓
therefore there are less (frequent) collisions ✓ — 2

(c) (i) 16–17 % ✓ — 1

(ii) as the temperature increases the conversion decreases ✓
(equilibrium) has moved to LHS/ has moved in endothermic direction ✓ — 2

(d) (i) increases ✓
because more collisions exceed (lowered) E_a/ because the catalyst provides an alternative route with a lower activation energy ✓ — 2

(ii) no change ✓
forwards and reverse rates increased by **same** amount ✓ — 2

[13]

8. sketch distribution to show axes labelled number/ fraction of molecules/atoms and
energy (1)
shape starting at origin, maximum, approaching but not crossing × axis (1) for **both** graphs
explanation of distribution
2 from
no molecules with no energy
few very energetic molecules
most have average amounts of energy
area under curve is the number of molecules (2)
distribution at higher temperature shown on diagram
hump lower than original (1)
and to RHS of original (1)
E_a marked (1)
rate increases with an increase in temperature (1) — 9
since more molecules have energy > E_a (1)

[9]

9.	(a)	to overcome activation energy (1) reaction is endothermic (1) to break bonds – if type of bonds stated must be ionic or covalent (1) A2 answer based on polarisation of carbonate by Ca^{2+} is acceptable		2
	(b)	(i)	rate forward > rate backward (1)	1
		(ii)	rate forward = rate backward (1)	1
		(iii)	equilibrium moves to RHS (1) use of le Chatelier (1) more CaO /product / less $CaCO_3$ / reactant present (1)	3

[7]

10.	(a)	anywhere in range 30 - 40% (1) if range given all values must be in this range		1
	(b)	(i)	increases (1)	1
		(ii)	more moles of A and B (1) equilibrium moves in direction of less moles (1)	2
	(c)	endothermic (marks for **explanation**) an increase in temperature converts more A (1) equilibrium moves in direction to lower temperature/ forward reaction must tend to lower temperature/ an increase in temperature favours the endothermic process (1)		2
	(d)	(i)	a substance that alters/increases the rate of reaction/lowers Ea (1) but remains unchanged **after the reaction** /is not used **up** (1)	2
		(ii)	to save **energy/money** + reason eg by allowing process to run at a lower temperature/ by lowering Ea (1) goes faster to save **time**/ allows the process to run continuously (1)	2
	(e)	not enough time was allowed for the equilibrium to establish/ other products were formed (1)		1

(f) two important catalysts, examples include
iron in Haber process/ manufacture of ammonia
vanadium(V) oxide in Contact process/ manufacture of sulphuric acid
nickel in hydrogenation of alkenes/ manufacture of margarines
phosphoric acid in the conversion ethene to ethanol
enzyme/ named enzyme with corresponding function
Pt/Pd/Rh in catalytic converter (any 1 metal)
Ziegler catalyst in alkene
any named acid (except nitric) in esterification
zeolites/ platinum in catalytic cracking — 2

[13]

11. (i) more CO and H_2/ less CH_3OH/ moves to LHS ✓
reaction is exothermic/ ora ✓ — 4
(moves in endothermic direction scores 1)

less CO and H_2/ more CH_3OH/ moves to RHS ✓
more mole/molecules/particles on LHS/ ora ✓

(ii) more particles per unit volume/
increased concentration/ particles closer together ✓
more collisions **and** increases rate✓ — 2

(iii) heterogeneous ✓ — 1

(iv) none ✓

affects forward and reverse reaction the **same** ✓ — 2

[9]

12. (a) the statement is true because there are more collisions (as temperature increases) ✓
increase in temperature increases the velocity/ energy of particles ✓
rate increases (with increase in temperature) more than can be explained by this/
but not all collisions are successful ✓
to be successful collisions must exceed E_a ✓
if temperature increased higher proportion of collisions exceed E_a ✓ — 5

(b) (i) *y* axis: fraction/ number of particles/ molecules/ atoms ✓ — 2
x axis: energy/ velocity ✓

(ii) line labelled T_2 with higher maximum ✓
maximum to LHS of original line ✓
(must start at 0.0, be below original curve at higher energies,
cut the other curve only once and not cross the × axis — 2

[9]

13. if the **conditions** on a system in **equilibrium** are changed (1)
the equilibrium moves to try to minimise the effects of the change (1)
[2]

14. (i) time less (1)
E_a lowered (1) 2
(ii) time less (1)
more collisions/ particles **exceed** $\mathbf{E_a}$ (1) 2
(iii) time more (1)
particles are **further apart** and therefore less (frequent) collisions (1) 2
[6]

15. (i) no effect because it only increases rate of reaction (1) 1
(ii) moves to LHS/ more N_2 and H_2/ less NH_3 (1)
forward reaction is exothermic (1) 2
(iii) moves to LHS / more N_2 and H_2/ less NH_3 (1)
fewer moles on RHS (1) 2
[5]

16. when the conditions on a system in equilibrium are changed (1)
the equilibrium moves to minimise the effects of the change/
counteract/ resist/ oppose the change (1)
[2]

17. (i) becomes brown/ darker/ colour more intense (1)
moves towards LHS/ towards NO_2 (1)
forward reaction is exothermic/ **reverse** reaction is endothermic (1) 3
(ii) becomes less brown/ pale/ colourless (1)
moves towards RHS/ towards N_2O_4 (1)
fewer moles on RHS (1) 3
[6]

18. catalyst alters rate of reaction/ lowers Ea (1)

remains unchanged **after** the reaction/ is not changed at the **end** of the reaction
BUT negated by does not take part in reaction (1)

[2]

19. *(When a system in dynamic equilibrium is subjected to a change in conditions....)*
the (position of) <u>equilibrium</u> will shift ✓
in the direction that <u>minimises the effect of /opposes</u> the change ✓
[NOT negates, nullifies or cancels]

[2]

20. Any two of the following bullet points ✓✓

- forward rate = reverse rate [NOT just "forward reaction = reverse reaction"]
- can be approached from either direction
  [*"forward rate of reaction = reverse rate of reaction"* is worth both the above bullet points]
- no change in overall macroscopic properties or a specific one (e.g. colour)
- takes place in a closed system
  [N.B. every wrong point negates a correct one]

[2]

21. (from yellow) to orange ✓
increasing $[H^+]$ *or* more acid/HC*l*
moves equilibrium/reaction to the left *or* produces more $Cr_2O_7^{2-}$ ✓

[2]

22. (i) turns lighter brown/colourless ✓
(equilibrium/reaction moves to the right):
fewer molecules/particles/moles on right *or* 2 moles $\rightarrow$ 1 mole ✓ 2

(ii) turns darker (brown) ✓
(equilibrium/reaction moves to the left): L$\rightarrow$R/forward rxn is exothermic. ✓ 2

[in (i) and (ii) mark the observation first, and then the reason. Each mark is unconditional on the other.] [in (ii), if neither mark is scored and you are convinced that the only error is mixing up endo/exo-thermic, you may award [1] mark]

[4]

23. (adding a catalyst):

- speeds up a reaction
- provides an alternative route *or* forms an intermediate of some sort
- of lower E_{act} (can be read into a label on a Boltzmann distribution)
- so more molecules have $E > E_{act}$ *or* more collisions are successful
- weakens bonds in the reactants

[any 4 points.] ✓✓✓✓

[5]

24. No mark scheme available

25. No mark scheme available

26. No mark scheme available