1(a)	large surface area / large area of contact / large surface; more (successful) collisions (between catalyst and gases or between reacting gases) **OR** more active sites **OR** faster reaction / increase rate / increase speed;	**2**	**I** activation energy Second mark must be comparative
(b)	decre temperature / temperature below 450 °C / quoted temperature below 450 °C; increase pressure / pressure above 200 atm / quoted pressure above 200 atm;	**2**	**I** comments about concentration **I** low temperature and high pressure. Both answers must be comparative **I** explanations
(c)	decreased <u>temperature</u> would reduce rate / reaction slow**<u>er</u>** / too slow; increased <u>pressure</u> expensive / uneconomic / safety risks / leaks / explosions / yield **or** rate good enough at lower pressure / strong pipes needed / thick pipes needed / sturdy pipes needed / requires a lot of energy;	**2**	**A** takes long**<u>er</u>** **I** slow (unqualified) **I** answers that do not refer to decreased temperature and increased pressure e.g. it is too expensive unless this is linked with pressure

2 **(a) (i)** pressure 150–300 atmospheres / atm (1)

temperature **accept** in range 370 to 470 °C (1)

iron (catalyst) (1)

balanced equation $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (1)

equilibrium / reversible (1) [5]

(ii) potassium / K (1)

phosphorus / P (1) [2]

(b) (i) burn fossil fuels / burn fuels containing sulfur / burn compounds containing sulfur / burn ores containing sulfur / roast metal sulfides / burn metal sulfides (1)

sulfur dioxide / SO_2 (formed) (1)

(form) sulfuric / H_2SO_4 / sulfurous acid / H_2SO_3 (1)

OR

nitrogen and oxygen (in air) react at high temperatures / in jet engines / car engines / lightning. (1)

(form) oxides of nitrogen (1)

(form) nitric acid / HNO_3 / nitrous acid / HNO_2 (1) [3]

(ii) any **two** from:
calcium oxide / lime / quicklime / CaO (1)
calcium hydroxide / $Ca(OH)_2$ / lime / slaked lime / limewater (1)
calcium carbonate / $CaCO_3$ / limestone / chalk / marble (1) [2]
guidance: 'lime' can only be credited once.

[Total: 12]

3 **(a (i)** any metal above zinc
$Mg \rightarrow Mg^{2+} + 2e$ [1]

(ii) $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$ [2]
Note: not balanced only [1]

(iii) because they can accept or gain electrons / change into atoms or can be reduced [1]

(iv) Ag^+ or silver [1]
charge not essential but if given must be correct

(v) Ag^+ and Cu^{2+} **or** silver and copper [1]
charge not essential but if given must be correct

(b) Cu Sn Cd Zn *(i.e. all **4** in correct order)* [1]
relates order to voltage [1]

one relevant comment from: [1]

higher reactivity metals are the negative electrode / copper is least reactive because it is the positive electrode because copper would have the lowest voltage / copper cell V = 0 / the bigger the difference in reactivity, the bigger the voltage / zinc has highest voltage because it is most reactive / more reactive metals have higher voltage

[Total: 9]

4 **(a) (i)** fractional distillation [1]
(liquid) air [1]

(ii) cracking / heat in presence of catalyst [1]
of alkane / petroleum [1]
to give an alkene and hydrogen [1]

OR: electrolysis (1)
named electrolyte (1)
hydrogen at cathode (1)

OR: from methane (1)
react water / steam (1)
heat catalyst (1)
only **ACCEPT:** water with methane **or** electrolysis

(b) (i) the pair with both graphs correct is C [1]
NOTE: mark **(b)(ii)** independent of **(b)(i)**

(ii) high pressure favours side with lower volume / fewer moles [1]
this is RHS / product / ammonia [1]
%NH_3 / yield increases as pressure increases [1]

the forward reaction is exothermic [1]
exothermic reactions favoured by low temperatures [1]
%NH_3 / yield decreases as temperature increases [1]
ACCEPT: reverse arguments

(iii) increases reaction rate [1]
ACCEPT: reduces activation energy [1]
OR: decreases the amount of energy particles need to react
OR: economic rate at lower temperature so higher yield

[Total: 14]

4 **(a) (i)** the (forward) reaction is endothermic [1]

(ii) none [1]
volume of reactants and products the same [1]
ACCEPT: number of moles or molecules

(iii) the reaction (between oxygen and nitric oxide) is <u>exothermic</u> [1]
high temperatures push equilibrium to left / high temperatures decrease yield of products / low temperatures favour forward reaction [1]

(iv) $4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ [2]
not balanced = (1) only

(v) (cost of) high amount of electricity / energy [1]

(b) (i) contains more nitrogen [1]

(ii) photosynthesis
chlorophyll is catalyst / chlorophyll absorbs light [1]
carbon dioxide and water react [1]
to make glucose / carbohydrates / starch / sugar / named sugar [1]

[Total: 13]

5 **(a)** (making) fertilisers / nitric acid / nylon / refrigeration / explosives / cleaning products; [1]

(b) alkane / named alkane; [1]
water / steam; [1]
heat / catalyst; [1]

or electrolysis; [1]
suggest suitable electrolyte; (**allow:** water) [1]
hydrogen at cathode; [1]

or cracking; [1]
alkane / named alkane; [1]
heat or catalyst [1]

(c) any five from:
faster; (rate) [1]

more collisions / molecules closer together / more particles per unit volume; [1]

(collisions) more frequent / more often / more chance / more effective or successful collisions / more collisions with Ea / increase rate of collisions; [1]

higher yield / moves (equilibrium) to RHS / more ammonia / to side of products / high pressure favours the reaction with less moles; [1]

less moles / molecules / volume on RHS ORA (can be implied in previous comments) [1]

high pressure means lower temperature can be used to achieve comparable rate (thus saving energy); [1]

6 **(d)** **(i)** endothermic takes in / absorbs / uses / needs / gains energy / heat **and** exothermic gives out / loses energy / heat; [1]

(ii) 2328 (ignore + or –) / 6 × 388 (not evaluated); [1]

944 + 1308 / 2252 **and** endothermic and exothermic in table; [1]

2328>2252 or (–) 76 kJ; [1]

or energy of products / RHS > reactants / LHS
or energy needed to break bonds < energy given out on formation of bonds.

[Total: 13]