1 Ammonia is manufactured by the Haber process. Nitrogen and hydrogen are passed over a catalyst at a temperature of 450 °C and a pressure of 200 atmospheres.

The equation for the reaction is as follows.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

The forward reaction is exothermic.

(a) State **one** use of ammonia.

..... [1]

(b) What is the meaning of the symbol $\rightleftharpoons$?

..... [1]

(c) What are the sources of nitrogen and hydrogen used in the Haber process?

nitrogen .....

hydrogen .....
[2]

(d) Name the catalyst in the Haber process.

..... [1]

(e) If a temperature higher than 450 °C was used in the Haber process, what would happen to the **rate** of the reaction? Give a reason for your answer.

.....

.....

..... [2]

(ii) If a temperature higher than 450 °C was used in the Haber process, what would happen to the **yield** of ammonia? Give a reason for your answer.

.....

.....

..... [2]

(f) If a pressur ocess, what would happen to the **yield** of ammonia? Give a reason for your answer.

.....

.....

..... [2]

(ii) Explain why the rate of reaction would be faster if the pressure was greater than 200 atmospheres.

.....

..... [1]

(iii) Suggest **one** reason why a pressure higher than 200 atmospheres is not used in the Haber process.

.....

..... [1]

(g) Draw a dot-and-cross diagram to show the arrangement of the outer (valency) electrons in one molecule of ammonia.

[2]

(h) Ammonia acts as a base when it reacts with sulfuric acid.

(i) What is a base?

..... [1]

(ii) Write a balanced equation for the reaction between ammonia and sulfuric acid.

..... [2]

[Total: 18]

2 Ammonia is made by the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The forward reaction is exothermic.
The conditions in the reaction chamber are:

- a pressure of 200 atmospheres,
- a catalyst of finely divided iron,
- a temperature of 400 to 450 °C.

(a) What are the **two** advantages of using a high pressure? Give a reason for both.

advantage 1 .....

reason .....

.....

advantage 2 .....

reason .....

.....

[4]

(b) A higher temperature would give a faster reaction rate.
Why is a higher temperature **not** used?

.....

.....

..... [3]

(c) Why is the iron catalyst used as a fine powder?

.....

..... [1]

(ii) Give **two** reasons why a catalyst is used.

.....

.....

.....

..... [2]

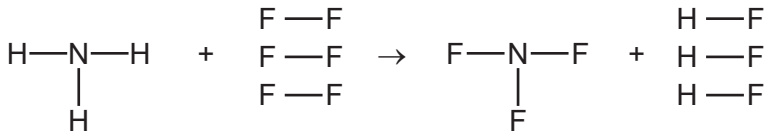
(d) The equilibrium mixture leaving the reaction chamber contains 15% ammonia. Suggest how the ammonia could be separated from the mixture.

	boiling point / °C
hydrogen	–253
nitrogen	–196
ammonia	–33

.....

..... [2]

(e) Ammonia is used to make nitrogen trifluoride, NF_3.
Nitrogen trifluoride is essential to the electronics industry. It is made by the following reaction.



Determine if the above reaction is exothermic or endothermic using the following bond energies and by completing the following table. The first line has been done as an example.
Bond energy is the amount of energy, in kJ / mole, needed to break or make one mole of the bond.

bond	bond energy in kJ / mole
N – H	390
F – F	155
N – F	280
H – F	565

bond	energy change / kJ
N – H	(3 × 390) = 1170
F – F	
N – F	
H – F	

.....

..... [4]

[Total: 16]

3 All metal nitrates decompose when heated. A few form a nitrite and oxygen. Most form the metal oxide, oxygen and a brown gas called nitrogen dioxide.

(a) (i) Name a metal whose nitrate decomposes to form the metal nitrite and oxygen.

..... [1]

(ii) Complete the equation for the action of heat on lead(II) nitrate.

$$\text{.....}Pb(NO_3)_2 \rightarrow \text{.....} + \text{.....}NO_2 + O_2$$ [2]

(iii) Suggest why the nitrate of the metal, named in **(a)(i)**, decomposes less readily than lead(II) nitrate.

.....

..... [2]

(b) Almost all samples of nitrogen dioxide are an equilibrium mixture of nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4.

$$\underset{\text{dark brown}}{2NO_2(g)} \underset{\text{reverse reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} \underset{\text{colourless}}{N_2O_4(g)}$$

In the forward reaction, a bond forms between the two nitrogen dioxide molecules.

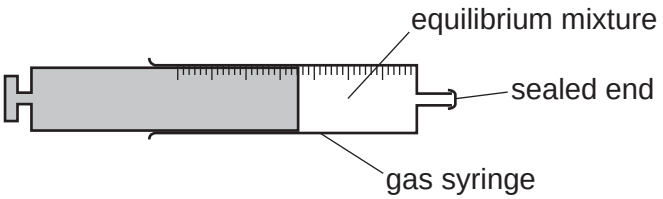
$$NO_2 + NO_2 \rightarrow O_2N-NO_2$$

(i) Explain the term *equilibrium mixture*.

.....

..... [1]

(ii) The syringe contains a sample of the equilibrium mixture. The plunger was pulled back reducing the pressure.
How would the colour of the gas inside the syringe change? Give an explanation for your answer.



.....

.....

..... [3]

(iii) A sealed tube containing an equilibrium mixture of nitrogen dioxide and dinitrogen tetroxide was placed in a beaker of ice cold water.
The colour of the mixture changed from brown to pale yellow.

Is the forward reaction exothermic or endothermic? Give an explanation for your choice.

.....

..... [2]

(iv) What other piece of information given in the equation supports your answer to **(iii)**?

$$NO_2 + NO_2 \rightarrow O_2N-NO_2$$

..... [1]

[Total: 12]

4 Nitrogen dioxide is a brown gas. It can be made by heating certain metal nitrates.

$$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$$

(a) Name another metal whose nitrate decomposes to give the metal oxide, nitrogen dioxide and oxygen.

..... [1]

(ii) Complete the word equation for a metal whose nitrate does not give nitrogen dioxide on decomposition.

metal nitrate $\rightarrow$ ..... + oxygen

[1]

(b) At most temperatures, samples of nitrogen dioxide are equilibrium mixtures.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

dark brown pale yellow

(i) At 25 °C, the mixture contains 20 % of nitrogen dioxide. At 100 °C this has risen to 90 %. Is the forward reaction exothermic or endothermic?
Give a reason for your choice.

.....

.....

..... [2]

(ii) Explain why the colour of the equilibrium mixture becomes lighter when the pressure on the mixture is increased.

.....

.....

..... [2]

(c) A 5.00 g sample of impure lead(II) nitrate was heated. The volume of oxygen formed was 0.16 dm^3 measured at r.t.p. The impurities did not decompose.
Calculate the percentage of lead(II) nitrate in the sample.

$$2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$$

Number of moles of O_2 formed = ...

Number of moles of $Pb(NO_3)_2$ in the sample = ...

Mass of one mole of $Pb(NO_3)_2$ = 331 g

Mass of lead(II) nitrate in the sample = ... g

Percentage of lead(II) nitrate in sample = ... [4]

[Total: 10]