Questions are for both separate science and combined science students unless indicated in the question

Q1.

This question is about sulfuric acid.

(a) Sulfuric acid contains sulfate ions.

Describe the test for the presence of sulfate ions in sulfuric acid.

Give the result of the test. **(chemistry only)**

Test _____

_____

Result _____

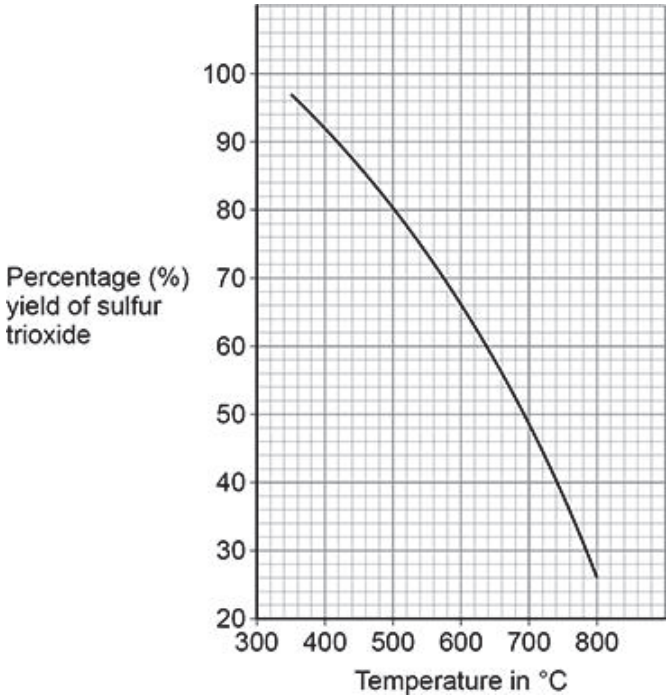
_____

(2)

One stage in the industrial production of sulfuric acid is the reaction of sulfur dioxide with oxygen to produce sulfur trioxide.

This reversible reaction reaches dynamic equilibrium.

The figure below shows the percentage yield of sulfur trioxide in this reaction at different temperatures.



(b) Which statement about the forward reaction is correct? **(HT only)**

Use the above figure.

Tick (✓) **one** box.

The yield is greater at higher temperatures because the reaction is exothermic.	☐
The yield is greater at higher temperatures because the reaction is endothermic.	☐
The yield is smaller at higher temperatures because the reaction is exothermic.	☐
The yield is smaller at higher temperatures because the reaction is endothermic.	☐

The equation for the reaction is:

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$

(1)

(c) Explain why the percentage yield of sulfur trioxide in this reaction is greater if the pressure is higher. **(HT only)**

_____

_____

_____

_____

(2)

(d) In industry, the reaction is done at 450 °C and atmospheric pressure.

Under these conditions the yield of sulfur trioxide is 86%.

Suggest **two** reasons why a higher pressure is **not** used. **(HT only)**

1 _____

_____

2 _____

_____

(2)

(e) This reaction uses a catalyst to increase the rate of the reaction.

The catalyst is a metal oxide.

Which is the most likely metal in the metal oxide catalyst? **(chemistry only)**

Use the periodic table.

Tick (✓) **one** box.

Aluminium (Al) ☐

Barium (Ba) ☐

Potassium (K) ☐

Vanadium (V) ☐

(1)

(Total 8 marks)

Q2.

This question is about reversible reactions.

When 4.68 g of hydrated copper sulfate changes into anhydrous copper sulfate:

- 2.99 g of anhydrous copper sulfate is produced
- 1.47 kJ of energy is taken in from the surroundings.

The equation for the reversible reaction is:

hydrated copper sulfate ⇌ anhydrous copper sulfate + water

(a) Calculate the maximum mass of water that can be produced from 11.7 g of hydrated copper sulfate. **(HT only)**

_____

_____

_____

_____

_____

Mass = _____ g

(3)

(b) 15.0 g of anhydrous copper sulfate completely changes into hydrated copper sulfate when water is added.

Calculate the amount of energy transferred to the surroundings. **(HT only)**

_____

_____

_____

Energy = _____ kJ

(2)

The gases nitrogen dioxide and dinitrogen tetroxide reach dynamic equilibrium in a sealed container.

The equation for the reaction is:

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

nitrogen dioxide (brown) — dinitrogen tetroxide (colourless)

The forward reaction is exothermic.

(c) What happens to the position of the equilibrium in this reaction if the temperature is increased? **(HT only)**

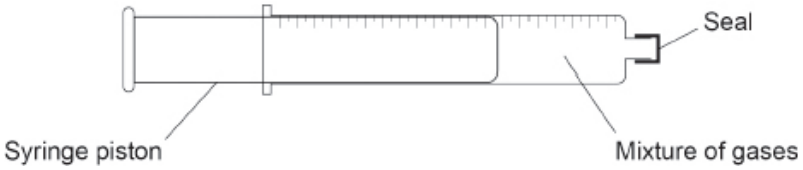
Tick (✓) **one** box.

- Shifts to the left ☐
- Stays the same ☐
- Shifts to the right ☐

(1)

(d) A teacher seals a brown-coloured mixture of nitrogen dioxide and dinitrogen tetroxide in a gas syringe.

The figure below shows the sealed gas syringe.



The teacher pushes the syringe piston in.

This increases the pressure in the gas syringe.

What is the colour of the mixture when a new equilibrium position is reached? **(HT only)**

Tick (✓) **one** box.

The mixture is a darker shade of brown.	☐
The mixture is the same shade of brown.	☐
The mixture is a lighter shade of brown.	☐

(1)

Hydrogen iodide gas decomposes into hydrogen gas and iodine gas at high temperatures.

The equation for the reaction is:

$$2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

(e) Explain the effect of increasing the pressure on the equilibrium position of this reaction. **(HT only)**

_____

_____

_____

_____

(2)

(f) Suggest the effect of adding a catalyst on the equilibrium position of this reaction. **(HT only)**

_____

_____

(1)

Copper forms coloured compounds.

Hydrochloric acid is added to an aqueous solution of copper compound **A**.

The word equation for the reaction is:

copper compound **A** (blue) + hydrochloric acid ⇌ copper compound **B** (yellow) + water

(g) The reaction mixture is green when both copper compounds are present in a solution at equilibrium.

How can the equilibrium position be shifted to make the reaction mixture more yellow? **(HT only)**

Tick (✓) **one** box.

Add more hydrochloric acid	☐
Add more water	☐
Leave the reaction mixture for 30 minutes	☐

(1)

(h) The concentrations of the substances in this reaction do **not** change at dynamic equilibrium. **(HT only)**

Explain why.

_____

_____

_____

_____

(2)

(Total 13 marks)

Q3.

Ammonia is produced in the Haber process.

The raw materials for the Haber process are nitrogen and hydrogen.

The equation for the reaction is:

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

(a) Give the sources of the nitrogen and of the hydrogen used in the Haber process. **(chemistry only)**

Nitrogen _____

Hydrogen _____

(2)

(b) How does the equation for the reaction show that the atom economy of the forward reaction is 100%? **(chemistry only)**

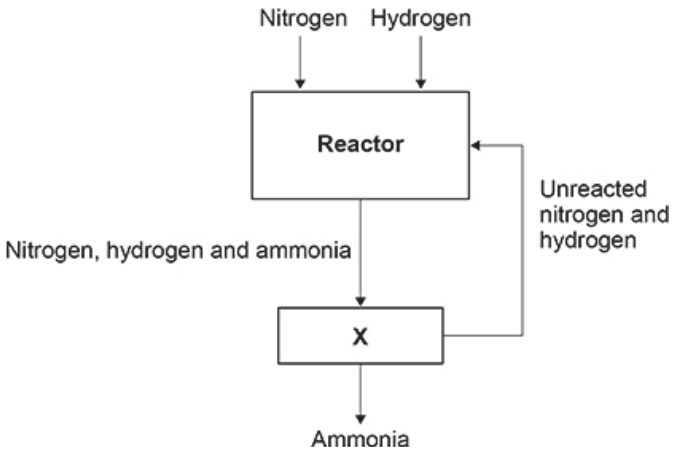
_____

_____

(1)

(c) **Figure 1** represents the Haber process.

Figure 1



Explain how the ammonia produced is separated from the unreacted nitrogen and hydrogen in **X**. **(chemistry only)**

_____

_____

_____

_____

(2)

The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

The table below shows the percentage yield of ammonia produced at 450 °C using different pressures.

Pressure in atmospheres	Percentage (%) yield of ammonia
60	9
120	18
180	25
240	31
300	36
360	40
420	43

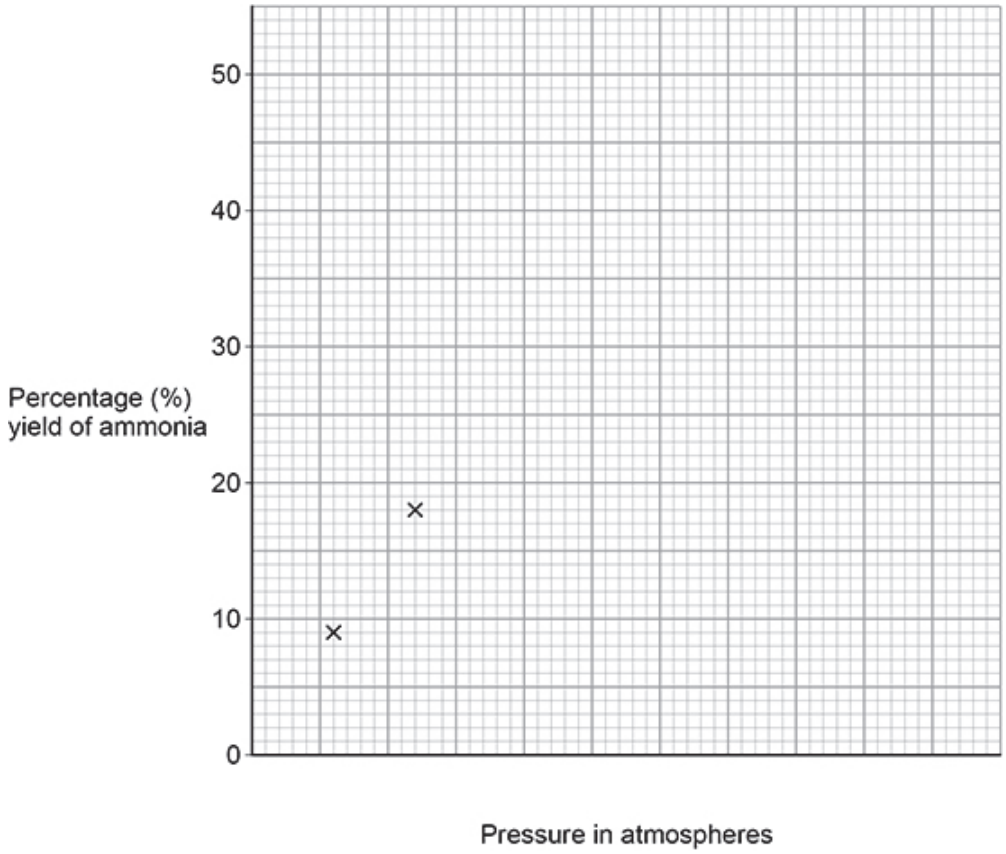
(d) Complete **Figure 2**. **(chemistry only)**

The first two points have been plotted.

You should:

- use a suitable scale for the *x*-axis
- plot the remaining data from the table above
- draw a line of best fit.

Figure 2



(4)

(e) Determine the percentage yield of ammonia at 450 °C and 500 atmospheres.
(chemistry only)

Show your working on **Figure 2**.

Percentage yield = _____%

(2)

(f) The equation for the production of ammonia in the Haber process is:

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

The forward reaction is exothermic.

The conditions used are:

- a temperature of 450 °C
- a pressure of 200 atmospheres
- the presence of an iron catalyst.

Explain why these conditions are chosen for economical production of ammonia in the Haber process. **(chemistry only)**

You should include references to the rate of reaction and the position of equilibrium.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 17 marks)