GCSE Chemistry

Reversible Reactions and Dynamic Equilibrium

Question Paper

Time available: 65 minutes
Marks available: 62 marks

1. This question is about copper sulfate.

Blue copper sulfate turns white when it is heated.

The word equation for the reaction is:

hydrated copper sulfate	⇌	anhydrous copper sulfate	+	water
blue		white		

(a) What name is given to hydrated copper sulfate in this reaction?

Tick **one** box.

- Catalyst ☐
- Element ☐
- Product ☐
- Reactant ☐

(1)

(b) What does the symbol ⇌ mean?

Tick **one** box.

- Endothermic ☐
- Exothermic ☐
- Reversible ☐
- Polymerisation ☐

(1)

(c) Complete the sentence.

The colour change when the water is added to anhydrous copper sulfate

is white to _____ .

(1)

A student heats 2.5 g of hydrate copper sulfate in a test tube.

0.9 g of water is given off.

The remaining solid is anhydrous copper sulfate.

(d) Calculate the mass of anhydrous copper sulfate produced.

_____

_____

Mass of anhydrous copper sulfate = _____ g

(2)

(e) Calculate the percentage of water contained in 2.5 g of hydrated copper sulfate.

_____

_____

_____

Percentage of water = _____ %

(2)

(f) Draw **one** line from each compound to the formula for the compound.

Compound	Formula for the compound
Copper sulfate	CuO
	CuS
	$CuSO_4$
Water	H_2O
	H_2SO_4

(2)

(Total 8 marks)

2. The Haber Process is used to produce ammonia from nitrogen and hydrogen.

The equation for the reaction is:

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

(a) An ammonia molecule has the formula NH_3

How many atoms are there in one molecule of ammonia?

Tick (✓) **one** box.

2 ☐ 3 ☐ 4 ☐ 6 ☐

(1)

(b) What does the symbol ⇌ mean?

_____

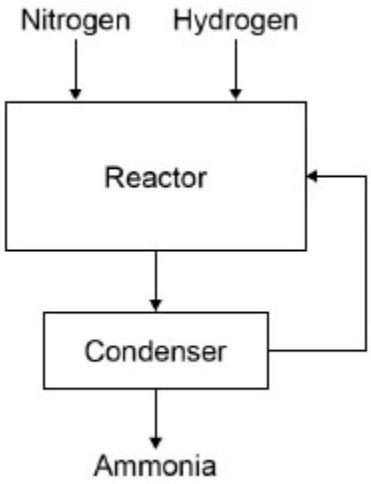
(1)

(c) Draw **one** line from each gas to the source of that gas.

Gas	Source
	Air
Hydrogen	Alcohol
	Ammonia
Nitrogen	Iron
	Natural gas

(2)

The diagram shows the Haber process.



A mixture of ammonia, hydrogen and nitrogen gases leave the reactor.

Table 1 shows the boiling points of the gases.

Table 1

Gas	Boiling point in °C
Ammonia	– 33
Nitrogen	– 196
Hydrogen	– 253

(d) The mixture is cooled to a temperature at which **only** the ammonia condenses to a liquid.

Which temperature could be used?

Tick (✓) **one** box.

− 20 °C ☐

− 40 °C ☐

− 200 °C ☐

− 260 °C ☐

(1)

(e) What happens to the unreacted nitrogen?

Tick (✓) **one** box.

- Collected and sold ☐
- Recycled to the reactor ☐
- Released into the air ☐
- Used as a catalyst ☐

(1)

Ammonia from the Haber process can be used to produce fertilisers.

Table 2 gives information about two compounds used in fertilisers.

Table 2

Fertiliser	Compound	Cost in £ / kg
A	Potassium chloride	0.24
B	Diammonium phosphate	0.35

(f) What type of bonding is present in potassium chloride?

Tick (✓) **one** box.

- Covalent ☐
- Ionic ☐
- Metallic ☐

(1)

(g) Diammonium phosphate has the chemical formula $(NH_4)_2HPO_4$

Which **two** elements in $(NH_4)_2HPO_4$ improve agricultural productivity?

Tick (✓) **two** boxes.

- Chlorine ☐
- Hydrogen ☐
- Nitrogen ☐
- Oxygen ☐
- Phosphorus ☐

A farmer uses fertilisers **A** and **B** on a field with an area of 0.05 km^2

(2)

(h) 50 kg of fertiliser A will cover an area of 0.01 km^2

Calculate the cost of fertilising a field with an area of 0.05 km^2 with fertiliser **A**.

Use **Table 2**.

_____

_____

Cost = £ _____

(2)

(i) Fertiliser **B** is more expensive than fertiliser **A**.

Suggest why the farmer uses **both** fertilisers.

_____

_____

(1)

(Total 12 marks)

3. This question is about ammonia and fertilisers.

(a) Ammonia is produced by a reversible reaction.

The equation for the reaction is:

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

Complete the sentence.

The forward reaction is exothermic, so the reverse reaction

is _____

(1)

(b) Calculate the percentage by mass of nitrogen in ammonia (NH_3).
Relative atomic masses (A_r): H = 1; N = 14
You **must** show how you work out your answer.

_____

_____

_____

_____

_____

_____

Percentage by mass of nitrogen = _____ %

(3)

(c) A neutral solution can be produced when ammonia reacts with an acid.

(i) Give the pH of a neutral solution.

pH _____

(1)

(ii) Which of these ionic equations shows a neutralisation reaction?

Tick (✓) **one** box.

$H^+ + OH^- \longrightarrow H_2O$ ☐

$NH_4^+ + OH^- \longrightarrow NH_4OH$ ☐

$H^+ + Cl^- \longrightarrow HCl$ ☐

$H^+ + H_2O \longrightarrow H_3O^+$ ☐

(1)

(iii) Name the salt produced when ammonia reacts with hydrochloric acid.

_____

(1)

(d) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

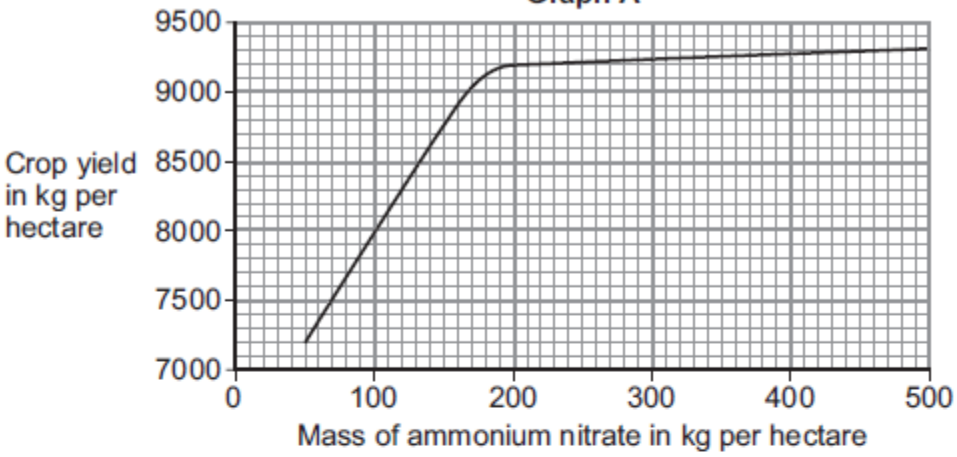
Farmers use ammonium nitrate as a fertiliser for crops.

Rainwater dissolves ammonium nitrate in the soil.

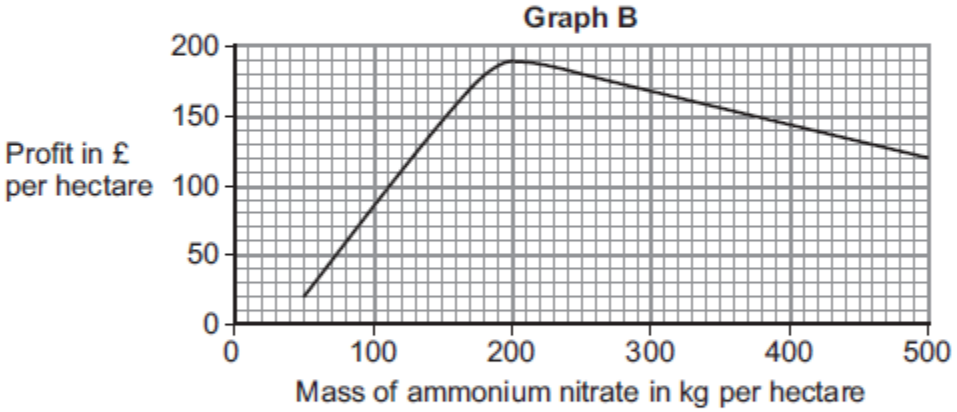
Some of the dissolved ammonium nitrate runs off into rivers and lakes.

The graphs **A**, **B** and **C** below show information about the use of ammonium nitrate as a fertiliser. A hectare is a measurement of an area of land.

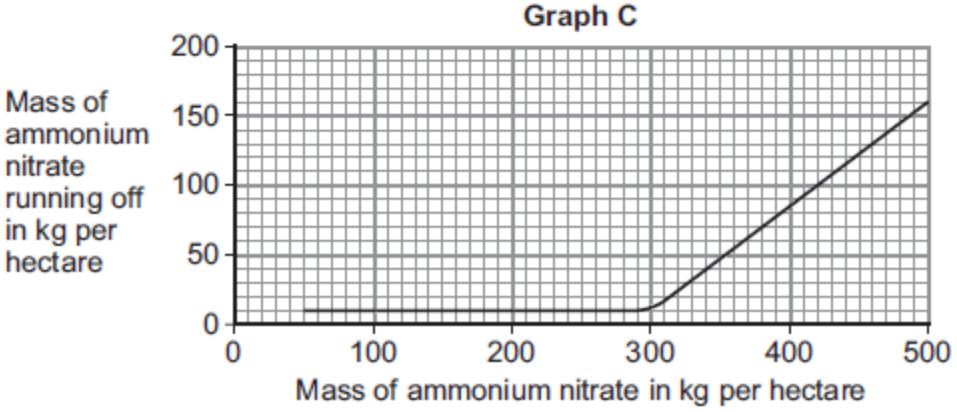
Graph A



Graph B



Graph C



Suggest how much ammonium nitrate farmers should use per hectare.

Give reasons for your answer.

Use information from graphs **A**, **B** and **C**.

(6)

(Total 13 marks)

4. A company manufactures ethanol (C_2H_5OH).

The reaction for the process is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

(3)

(b) (i) How would increasing the temperature change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

(2)

(ii) How would increasing the pressure change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

(2)

(c) A catalyst is added to increase the rate of the reaction.

Explain how adding a catalyst increases the rate of a chemical reaction.

_____

_____

_____

_____

(2)

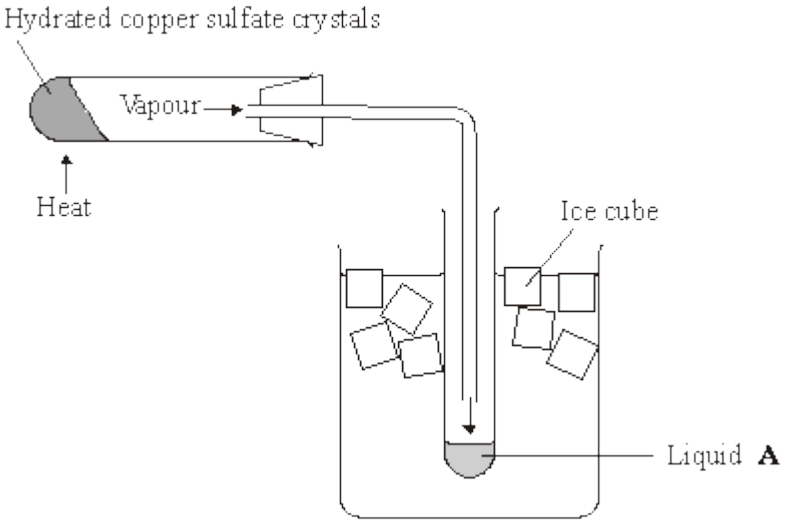
(Total 9 marks)

5. A student heated some hydrated copper sulfate crystals.
The equation for this reaction is shown below.

$CuSO_4.5H_2O(s)$ ⇌ $CuSO_4(s) + 5H_2O(1)$

hydrated copper sulfate crystals ⇌ anhydrous copper sulfate + water

The diagram shows the apparatus used.



(a) Name liquid **A** _____

(1)

(b) What helped the vapour to condense into liquid **A**?

_____

_____

(1)

(c) Put a tick (✓) next to the correct meaning of the symbol $\rightleftharpoons$

Meaning	(✓)
equal amounts of reactants and products	
exothermic reaction	
reversible reaction	

(1)

(d) The student weighed the copper sulfate before and after it was heated.
The experiment was repeated and the two sets of results are shown in the table.

Mass of copper sulfate before heating in grams	Mass of copper sulfate after heating in grams	Mass lost in grams
2.50	1.65	0.85
2.50	1.61	0.89

(i) Draw a ring around the **average** mass lost for these two sets of results.

0.85 g **0.87 g** **0.89 g**

(1)

(ii) The student used the same mass of copper sulfate each time but the mass lost was different.

Put a tick (✓) next to the **two** reasons which could explain why the mass lost is different.

Reason	(✓)
The student used different test tubes for the two experiments.	
The student made errors in weighing during the experiments.	
The student used more ice in one of the experiments.	
The student did not heat the copper sulfate for long enough in one of the experiments.	

(2)

(e) Anhydrous copper sulfate is used to test for water.

Use words from the box to complete the sentence.

blue	**green**	**red**	**white**

Water changes the colour of anhydrous copper sulfate from

_____ to _____ .

(2)

(Total 8 marks)

6. This question is about methanol.

(a) Methanol is broken down in the body during digestion.

What type of substance acts as a catalyst in this process?

Tick **one** box.

- Amino acid ☐
- Enzyme ☐
- Ester ☐
- Nucleotide ☐

(1)

In industry, methanol is produced by reacting carbon monoxide with hydrogen.

The equation for the reaction is:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

(b) How many moles of carbon monoxide react completely with 4.0×10^3 moles of hydrogen?

Tick **one** box.

1.0×10^3 moles ☐

2.0×10^3 moles ☐

4.0×10^3 moles ☐

8.0×10^3 moles ☐

(1)

(c) The reaction is carried out at a temperature of 250 °C and a pressure of 100 atmospheres.

The forward reaction is exothermic.

Explain what happens to the yield of methanol if a temperature higher than 250 °C is used.

_____

_____

_____

_____

(2)

(d) A pressure of 100 atmospheres is used instead of atmospheric pressure.

The higher pressure gives a greater yield of methanol and an increased rate of reaction. Explain why.

(4)

A catalyst is used in the reaction to produce methanol from carbon monoxide and hydrogen.

(e) Explain how a catalyst increases the rate of a reaction.

(2)

(f) Suggest why a catalyst is used in this industrial process.

Do **not** give answers in terms of increasing the rate of reaction.

(1)

(g) Suggest the effect of using the catalyst on the equilibrium yield of methanol.

_____

_____

(1)

(Total 12 marks)