GCSE Chemistry Edexcel

Equilibrium

Past paper questions booklet

Questions

Q9.

When nitrogen and hydrogen react to form ammonia, the reaction can reach a dynamic equilibrium.

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

(a) Explain what is meant by a **dynamic equilibrium.**

(2)

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(b) In industry, the reaction between nitrogen and hydrogen is affected by the conditions used.

(i) The pressure used is 250 atmospheres.

Explain how the use of a higher pressure would affect the equilibrium yield of ammonia.

(2)

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(ii) The reaction between nitrogen and hydrogen to form ammonia is exothermic. The temperature used is 450°C.

Explain how the use of a lower temperature would affect the equilibrium yield of ammonia.

(2)

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(ii) The reaction between nitrogen and hydrogen to form ammonia is exothermic.

The temperature used is 450°C.

Explain how the use of a lower temperature would affect the equilibrium yield of ammonia.

(2)

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(iii) Even at 450°C, the reaction is very slow.

State what is used in industry to overcome this problem.

(1)

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(c) (i) Calculate the minimum volume of hydrogen required to completely convert 1000 dm^3 of nitrogen into ammonia.

(1)

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volume of hydrogen = ... dm^3

(ii) Ammonia is reacted with excess nitric acid, HNO_3, to make ammonium nitrate, NH_4NO_3.

$NH_3 + HNO_3 \rightarrow NH_4NO_3$

Calculate the mass of ammonium nitrate produced by the complete reaction of 34 g of ammonia.

(Relative atomic masses H = 1.0, N = 14, O = 16)

(3)

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mass of ammonium nitrate produced =.....g

(Total for Question = 11 marks)

Q10.

When nitrogen and hydrogen react to form ammonia, the reaction can reach a dynamic equilibrium.

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

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(i) The pressure used is 250 atmospheres.

Explain how the use of a higher pressure would affect the equilibrium yield of ammonia.

(2)

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Explain how the use of a lower temperature would affect the equilibrium yield of ammonia.

(2)

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(iii) Even at 450°C, the reaction is very slow.

State what is used in industry to overcome this problem.

(1)

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Q11.

Most metals are extracted from ores found in the Earth's crust.

The method used to extract a metal from its ore is linked to the reactivity of the metal.

Part of the reactivity series is shown in Figure 2.

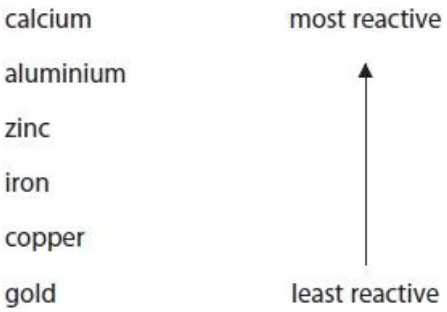

Figure 2

Iron ore contains iron oxide.

Iron is extracted from iron oxide by heating the oxide with carbon.

$$\text{iron oxide} + \text{carbon} \rightarrow \text{iron} + \text{carbon dioxide}$$

(i) In this reaction

(1)

- ☒ **A** carbon is reduced
- ☒ **B** iron oxide is neutralised
- ☒ **C** iron oxide is reduced
- ☒ **D** iron is oxidised

(ii) The formula of the iron oxide is Fe_2O_3.

Calculate the maximum mass of iron that can be obtained from 240 tonnes of iron oxide, Fe_2O_3.
(relative atomic masses: O = 16, Fe = 56)

(3)

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mass of iron = ... tonnes

(Total for question = 4 marks)

Q12.

Gases and ammonia

(a) Hydrogen reacts with oxygen to form water vapour.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

If 200 cm^3 of hydrogen react completely with 100 cm^3 of oxygen, what is the maximum volume of water vapour formed, if all volumes are measured at the same temperature and pressure?
Put a cross (☒) in the box to show your answer.

(1)

☒ **A** 100 cm^3

☒ **B** 200 cm^3

☒ **C** 300 cm^3

☒ **D** 400 cm^3

(b) Zinc reacts with dilute hydrochloric acid to form zinc chloride and hydrogen.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Calculate the maximum volume of hydrogen formed, at room temperature and pressure, when 13.0 g of zinc reacts completely with excess hydrochloric acid.
(relative atomic mass: Zn = 65.0,
1 mol of any gas occupies 24 dm^3 at room temperature and pressure)

(2)

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volume of hydrogen = ... dm^3

(c) In industry, ammonia is produced by the Haber process.

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

(i) What is the source of the hydrogen used in the Haber process?
Put a cross (☒) in the box to show your answer.

(1)

- ☒ **A** air
- ☒ **B** reaction of zinc with dilute sulfuric acid
- ☒ **C** electrolysis of water
- ☒ **D** natural gas

(ii) When nitrogen reacts with hydrogen, the amount of ammonia gradually increases until it becomes constant.

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

Explain why the amount of ammonia remains constant.

(2)

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*(d) The reaction between nitrogen and hydrogen is exothermic.

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

If nitrogen and hydrogen were reacted at 90 atm pressure and 300 °C, without a catalyst, some ammonia would be formed eventually.
In the Haber process a pressure of 150 atm and a temperature of 450 °C are used, in the presence of an iron catalyst.
Explain, with reasons, why the Haber process conditions are better for the manufacture of ammonia.

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(Total for question = 12 marks)

Q13.

Nitrogen reacts with hydrogen to form ammonia.

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

(i) Calculate the minimum volume of nitrogen, in dm^3, required to react completely with 1000 dm^3 of hydrogen.

All volumes are measured at the same temperature and pressure.
Put a cross (☒) in the box next to your answer.

(1)

☐ **A** 333 dm^3

☐ **B** 1000 dm^3

☐ **C** 3000 dm^3

☐ **D** 4666 dm^3

(ii) The minimum volumes of nitrogen and hydrogen that must react completely to form 5000 dm^3 of ammonia are calculated.

These volumes are mixed and left, under appropriate conditions, until the reaction reaches equilibrium.
Explain which gas or gases will be present when equilibrium is reached.

(2)

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(iii) The Haber process is carried out under a pressure of about 200 atm.

Explain the effect on the **equilibrium yield** of ammonia, if the process is carried out at a pressure higher than 200 atm.

(2)

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(iv) Explain the effect on the **rate of attainment of equilibrium**, if the process is carried out at a pressure higher than 200 atm.

(3)

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Q14.

Most metals are extracted from ores found in the Earth's crust.

The method used to extract a metal from its ore is linked to the reactivity of the metal.

Part of the reactivity series is shown in Figure 2.

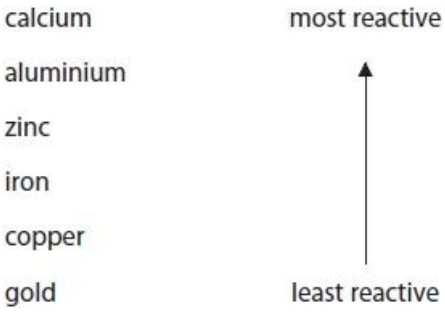

Figure 2

Predict the method that will have to be used to extract calcium from its ore.

(1)

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(Total for question = 1 mark)

Q15.

A student placed a piece of metal **P** in a test tube containing excess dilute sulfuric acid.
The student repeated this with three other metals, **Q**, **R** and **S**.
All the pieces of all four metals were the same size.

(i) The student recorded the observations until each metal had reacted with the acid for two minutes.

The observations are shown in Figure 9.

metal	observations
P	bubbles produced very slowly some metal remained
Q	bubbles produced quickly no metal remained
R	bubbles produced slowly no metal remained
S	bubbles produced very quickly no metal remained

Figure 9

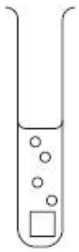
Use this information to put the four metals in order of reactivity from the least reactive to the most reactive.

(2)

least reactive | | | | | **most reactive**

(ii) Complete the diagram below to show how the student could add to the apparatus to measure the volume of gas produced in the two minutes.

(2)



(Total for question = 4 marks)

Mark Scheme

Q9.

	Answer	Acceptable answers	Mark
(a)	An explanation linking Marking point 1 – one from • forward and back reactions take place (at the same time) (1) • rate of the forward and back reactions is the same (1)Marking point 2 – one from • no (overall) change in the amount/concentration/mas s/ volume of each substance / reactant / product (1) • no observable change (1)	assume 'both reactions' implies the forward and back reaction allow reversible reaction with the same rate (1) allow reversible reaction in a closed system (1) do not allow the forward reaction equals the reverse reaction allow overall effect is nil (1) allow reactants and products reach a balance (1) ignore forward reaction cancels out back reaction do not allow amount / concentration /mass/volume of reactants and products are equal	**(2)**
(b)(i)	An explanation linking two of • higher pressure favours forward reaction/equilibrium shifts to the right (1) • because decrease in volume / number of molecules/side with lower volume (1) • yield increases (1)	ignore answers related to rate/collisions maximum (1) if 3 statements given, but 1 is incorrect	**(2)**
(b)(ii)	An explanation linking any two of • lower temperature favours forward reaction/equilibrium shifts to the right (1) • because	ignore answers related to rate/collisions if answer refers to increasing temperature, maximum (1) for (forward) reaction is	**(2)**

	(forward) reaction is exothermic (1) • yield increases (1)	exothermic / reverse reaction is endothermic maximum (1) if 3 statements given, but 1 is incorrect	
(b)(iii)	catalyst	iron	**(1)**
(c)(i)	3 × 1000 (1) (= 3000)		**(1)**
(c)(ii)	marks are for the working Method 1 14 + (3 × 1) (1) g of NH_3 makes 14 + (4 × 1) + 14 + (3 × 16) (1) g NH_4NO_3 34 g of NH_3 makes $\frac{(14 + (4 \times 1) + 14 + (3 \times 16)) \times 34}{17}$ or $\frac{80 \times 34}{17}$ or 2(14 + (4 × 1) + 14 + (3 × 16)) g NH_4NO_3 (1) = 160 Method 2 moles of NH_3 = $^{34}/_{17}$ (1) = 2 moles of NH_4NO_3 = moles of NH_3 or relative formula mass NH_4NO_3 = 80 (1) mass NH_4NO_3 = 2 x 80 (1) = 160 g	full marks awarded for an answer of 160 g with or without any working allow ecf on incorrect Mr s for either method allow ecf for incorrect moles eg if moles of NH_3 = 0.5 relative formula mass NH_4NO_3 = 80 (1) mass NH_4NO_3 = 0.5 × 80 (1) = 40 g	**(3)**

Q10.

	Answer	**Acceptable answers**	**Mark**
(i)	An explanation linking two of • higher pressure favours forward reaction/equilibrium shifts to the right (1) • because decrease in volume / number of molecules/side with lower volume (1) • yield increases (1)	ignore answers related to rate/collisions maximum (1) if 3 statements given, but 1 is incorrect	**(2)**
(ii)	An explanation	ignore answers	**(2)**

	linking any two of • lower temperature favours forward reaction/equilibrium shifts to the right (1) • because (forward) reaction is exothermic (1) • yield increases (1)	related to rate/collisions if answer refers to increasing temperature, maximum (1) for (forward) reaction is exothermic / reverse reaction is endothermic maximum (1) if 3 statements given, but 1 is incorrect	
(iii)	catalyst	iron	**(1)**

Q11.

Question Number	Answer	Mark
(i)	**C** iron oxide is reduced **The only correct answer is C** ***A*** *is not correct because carbon gains oxygen* ***B*** *is not correct because it is not an acid-base reaction* ***D*** *is not correct because iron oxide loses oxygen*	**(1)** AO 1 1

Question Number	Answer	Additional guidance	Mark
(ii)	final answer of 168 (tonnes) with or without working (3) OR relative formula mass Fe_2O_3 = 2x56 + 3x16 (= 160) (1) 160 tonnes Fe_2O_3 produces {2x56 / 112} tonnes Fe (1) 240 tonnes Fe_2O_3 produces $\frac{2x56}{160}$ x 240 (1) = 168 (tonnes) OR relative formula mass Fe_2O_3 = 2x56 + 3x16 (= 160) (1) $\frac{240}{160}$ (1) = 1.5 1.5 x 112 (1) = 168 (tonnes) OR relative formula mass Fe_2O_3 = 2x56 + 3x16 (= 160) (1) $\frac{112}{160}$ (1) = 0.7 0.7 x 240 (1) = 168 (tonnes)	allow ECF throughout M_r [Fe_2O_3]= 160 seen without working (1) allow 320 tonnes : 224 tonnes (1) final answer 84 (tonnes) with or without working (2) Note : final answer 1.5 scores 2 overall	(3) AO 2 1

Q12.

Question Number	Answer	Acceptable answers	Mark
(a)	**B** 200 cm^3		**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)	65.0 g Zn produces 24 dm^3 H_2 (1) 13.0 g Zn produces $\frac{13.0}{65.0}$ x 24 (1) (= 4.8 dm^3 H_2)	$\frac{13.0}{65.0}$ mol Zn produces $\frac{13.0}{65.0}$ mol H_2 Vol of H_2 = $\frac{13.0}{65.0}$ x 24 (2) (= 4.8dm^3) 4.8 dm^3 (2) without working allow 65/13 x 24 (1) = 120dm^3 13/65 (1) x (1/24) = 0.00833 dm^3 0.2 anywhere 1 mark x 24 anywhere 1 mark	**(2)**

Question Number	Answer	Acceptable answers	Mark
(c)(i)	**D** natural gas		**(1)**

Question Number	Answer	Acceptable answers	Mark
(c)(ii)	An explanation linking forward and back reactions take place / reversible / dynamic (1) at the same rate / equilibrium (1)	dynamic equilibrium = 2 marks	**(2)**

Question Number		Indicative Content	Mark
QWC	*** (d)**	A description including some of the following points Higher pressure: • higher pressure gives increased yield • equilibrium shifts to right hand side • because decrease in number of molecules going from left to right • therefore decrease in volume • favoured by increase in pressure • reaches equilibrium faster • because molecules closer together • so get more frequent collisions Higher temperature • higher temperature reaches equilibrium faster • because molecules move faster • therefore more frequent collisions • molecules have more energy • therefore more collisions have required energy • but yield will be lower • because higher temperature favours endothermic reaction • equilibrium shifts to left hand side • which is decomposition of ammonia / ammonia reforms elements Use of catalyst • catalyst causes reaction to reach equilibrium faster / catalyst increases rates (of both forward and back reactions) • *lowers the activation energy (of both forward and back reactions)* • *reaction follows a new pathway* • does not affect yield • equilibrium position not affected	**(6)**

Level	**0**	No rewardable content
1	**1 - 2**	• a limited description e.g. one valid effect of change OR general comment indicating improved yield or faster rate • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy
2	**3 - 4**	• a simple description e.g. at least two valid effects of change with one point of explanation OR at least three valid effects of change • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy
3	**5 - 6**	• a detailed description e.g. at least three valid effects of change with two points of explanation OR at least two valid effects with three points of explanation (in total) • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors

Q13.

Question Number	Answer	Acceptable answers	Mark
(i)	**A** 333 dm^3		**(1)**

Question Number	Answer	Acceptable answers	Mark
(ii)	An explanation linking • <u>all / three</u> gases present/ <u>nitrogen, hydrogen and ammonia</u> (1) • ammonia decomposes/ ammonia turns back to reactants/ reaction goes both ways / reversible (1)	reject ammonium ignore incomplete reaction assume that "both reactions" refer to forward and backward reaction allow **<u>dynamic</u>** equilibrium	**(2)**

Question Number	Answer	Acceptable answers	Mark
(iii)	An explanation linking • increased / high**er** {yield / amount of ammonia} (1) • because fewer (gas) molecules/ moles on RHS/ 4 mole(cule)s on left and 2 on right/ decreased volume on RHS/equilibrium shifts to RHS/ equilibrium shifts in forward direction (1)	mark independently ignore "high yield" reject answers referring to exothermic or endothermic ignore any references to rate	**(2)**

Question Number	Answer	Acceptable answers	Mark
(iv)	An explanation to include • **<u>rate</u>** increased/ time to reach equilibrium reduced (1) • because gas molecules closer / more concentrated (1) • so increased **collision** <u>rate</u> / more **collisions** <u>in a given time</u> / more <u>frequent</u> **collisions**(1)	mark independently ignore any refs to equilibrium ignore 'time is faster'/ allow 'quicker' allow atoms/ particles instead of molecules; allow more molecules present (in same container) do not allow 'more collisions'	**(3)**

Q14.

Question Number	Answer	Mark
	electrolysis	**(1)** AO 3 2a

Q15.

Question Number	Answer	Additional guidance	Mark
(i)	P R Q S (2)	two in correct order (1)	**(2)** AO 3 2a AO 3 2b

Question Number	Answer		Mark
(ii)	A workable diagram showing a method to measure the volume of the gas • delivery tube between test-tube and (1) • gas syringe / (graduated tube / inverted burette / measuring cylinder) over water bath (1)	if diagram is not workable (eg no bung at top of test tube), max 1 mark allow connection shown as  if collection vessel not labelled, graduations must be shown for the second mark	**(2)** AO 3 3a AO 3 3b