INSIGHT

Year 11 *Trial Exam Paper*

2012

CHEMISTRY

Written examination 2

Solutions Book

This book presents:

- correct solutions with full working
- explanatory notes
- mark allocations
- tips and guidelines

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SECTION A – Multiple-choice questions

Question 1

The best representation of a water molecule is

A. H–O–H

B. $H^{\delta+}$–$O^{\delta-}$
  |
  $H^{\delta+}$

C. **$H^{\delta+}$–$O^{\delta-}$**
  \
  $H^{\delta+}$

D. $H^{\delta-}$– $O^{\delta+}$
  \
  $H^{\delta-}$

Answer is C

Worked solution

- C is correct. It shows that water has dipoles and that it is a V-shaped molecule.
- A is incorrect as water is not linear and dipoles are not shown.
- B is incorrect as the angle of the V comes from a tetrahedral arrangement and is not 90°.
- D is incorrect as the polarity of the dipoles is the reverse of the correct answer.

Tip

The properties of water are the result of its strong hydrogen bonding. An understanding of this hydrogen bonding will often be useful in other questions about water.

Question 2

A saucepan filled with water and pasta sits boiling on a hot plate. Although the water is sitting on a hot plate, the temperature of the water remains at 100°C. The reason the temperature is not rising is that

A. **the energy from the hot plate is used to break the bonds between the water molecules**
B. water has a high specific heat capacity
C. water has a high latent heat of fusion
D. the energy from the hot plate is all lost to the surroundings

Answer is A

Worked solution

- A is correct. Water has a high latent heat of vaporisation. Considerable energy is required to separate the water molecules to form steam. The temperature will not increase until the water has all evaporated.
- B is a correct statement about water but it does not relate to the energy required to cause the water to change from the liquid state to the gaseous state.
- C is a correct statement about water but it refers to melting ice and not to boiling water.
- D is incorrect; the energy from the hot plate is required to break bonds between the water molecules.

Question 3

The water in a car radiator is often at temperatures above 110°C when the car engine is running. Despite the temperature, the water still exists as a liquid. The main reason for this is that

A. cars usually have highly inaccurate temperature gauges
B. **the high pressure in the radiator prevents the water from boiling**
C. the purity of the water is very low
D. the water always cools very quickly to temperatures below 100°C

Answer is B

Worked solution

- B is correct. The boiling point of a liquid can vary significantly if the air pressure is varied. A car radiator can maintain very high pressures, making the boiling point of water considerably higher than the expected value.
- A is incorrect as the water in the radiator could well be over 110°C.
- C is incorrect. The same effect would be evident if pure water was used.
- D is incorrect as the temperature often remains at high values while the engine is running.

Tip

A sound general knowledge of science helps with this question and with many aspects of senior science. What you study in the class should always be related to what you see in the real world.

Question 4

A 375 mL bottle of lemonade contains 65 g of sugar. The concentration of the sugar, in % m/v, is

A. 6.5
B. **17**
C. 21
D. 65

Answer is B

Worked solution

- B is correct, as the calculation below shows.

$$\%\ \text{m/v} = \frac{\text{mass solute}}{\text{volume solution}} \times \frac{100}{1} = \frac{65}{375} \times 100 = 17\%$$

- A is incorrect as it is too low.
- C is incorrect. The volume of the whole drink needs to be used and this is 375 mL.
- D is incorrect, as it is far too high.

Tip

There are many units for concentration, not just molarity. The unit often tells you what calculation to do; for example, % m/v, virtually tells you to divide the mass by the volume.

Question 5

Which solution will contain the greatest mass of sodium hydroxide?

A. **200 mL of 0.4 M NaOH**
B. 2 g of NaOH dissolved in 200 mL
C. 100 mL of 0.7 M NaOH
D. 10 mL of 2.0 M NaOH

Answer is A

Worked solution

- A is correct. The mass can be calculated for each option and A comes out with the highest value.
  $n(\text{NaOH}) = c \times V = 0.4 \times 0.2 = 0.08$ mole
  $\text{mass(NaOH)} = m \times M = 0.08 \times 40 = 3.2$ g
- B is incorrect as 2 g is less than 3.2 g.
- C is incorrect. $n(\text{NaOH}) = 0.7 \times 0.1 = 0.07$ mole, which is less than A.
- D is incorrect. $n(\text{NaOH}) = 2 \times 0.01 = 0.02$ mole, which is less than A.

Tip

Some of the options should be easy to discount. Option D is obviously a lower number of moles than C. It is important to save time by avoiding unnecessary calculations.

Question 6

An acid is best defined as a substance that

A. contains hydrogen
B. contains oxygen
C. can react with a metal in a chemical reaction
D. **can donate a proton in a chemical reaction**

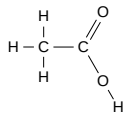
Answer is D

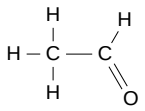
Worked solution

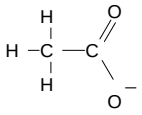
- D is correct. The accepted Lowry–Bronsted definition of an acid is that it can donate a proton.
- A is incorrect. This was an early definition of an acid, but substances such as CH_4 contain hydrogen but are not acidic.
- B is incorrect. Many acids such as HCl do not contain oxygen.
- C is incorrect. A very weak acid might not react with a metal but it is still an acid.

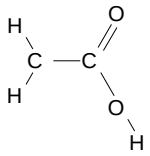
Question 7

Ethanoic acid has the formula CH_3COOH. When an ethanoic acid molecule acts as an acid, the conjugate base formed is

A. 

B. 

C. 

D. 

Answer is C

Worked solution

- C is correct. The equation is:
  $CH_3COOH(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CH_3COO^-(aq)$
- A is incorrect as it shows no change to the CH_3COOH.
- B is incorrect as it has donated an oxygen not a hydrogen.
- D is incorrect as it shows the wrong hydrogen donated.

Question 8

Consider the solutions shown:

0.01 M NaOH 1.0 M HCl 1.0 M NaCl 0.1 M CH_3COOH

The solution with the highest pH will be

A. **0.01 M NaOH**
B. 1.0 M HCl
C. 1.0 M NaCl
D. 0.1 M CH_3COOH

Answer is A

Worked solution

- A is correct. It is the only base listed, so it will have the highest pH.
- B is incorrect as a strong acid will have a low pH.
- C is incorrect as NaCl is neutral.
- D is incorrect as ethanoic acid is a weak acid.

Tip

Don't get caught out by the seeming contradiction 'as the acid gets stronger the pH gets lower'. This question is NOT asking for the strongest acid.

Question 9

In a 0.01 M solution of HCl, the pH, the hydronium ion concentration and the hydroxide ion concentration will be

	pH	$[H_3O^+]$ (M)	$[OH^-]$ (M)
A.	1	0.01	0.13
B.	2	0.01	0.13
C.	2	10^{-1}	10^{-1}
D.	**2**	$\mathbf{10^{-2}}$	$\mathbf{10^{-12}}$

Answer is D

Worked solution

- D is correct. If pH = 2 then $[H_3O^+] = 10^{-2}$ and $[OH^-]$ will be $10^{-14}/10^{-2} = 10^{-12}$
- A is incorrect as $[H_3O^+]$ is wrong. The pH is also wrong.
- B is incorrect as $[H_3O^+]$ is wrong.
- C is incorrect as $[H_3O^+]$ is wrong.

Tip

You need to be able to convert pH values back to $[H_3O^+]$, for example
pH = 1, then $[H_3O^+] = 10^{-1}$
pH = 3, then $[H_3O^+] = 10^{-3}$
etc.

Question 10

The reaction between iron and sulfur is

$2Fe(s) + 3S(s) \rightarrow Fe_2S_3(s)$

When 0.28 mole of iron reacts with 0.42 mole of sulfur the

A. sulfur is in excess
B. iron is in excess
C. **iron and sulfur are in the correct ratio to react completely**
D. number of mole of product formed will be 0.28

Answer is C

Worked solution

- C is correct. The mole ratio between Fe and S should be 2:3. $0.28 \times \frac{3}{2} = 0.42$, which is option C.
- A is incorrect as sulfur is not in excess.
- B is incorrect as iron is not in excess.
- D is incorrect as 0.14 mole of Fe_2S_3 will form.

Question 11

A titration is conducted to determine the concentration of a nitric acid solution. A 20.0 mL aliquot of 0.100 M sodium hydroxide is neutralised by 16.0 mL of nitric acid. The concentration of the nitric acid is

A. 0.080 M
B. 0.100 M
C. **0.125 M**
D. 0.250 M

Answer is C

Worked solution

- C is correct. A titration calculation needs to be completed.
  $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$
  $n(NaOH) = c \times V = 0.02 \times 0.1 = 0.002$ mole
  $n(HNO_3) = n(NaOH) = 0.002$
  $c(HNO_3) = \frac{n}{v} = \frac{0.002}{0.016} = 0.125$ M
- A is incorrect as it has mixed up the two volumes in the calculation.
- B is incorrect as the concentrations cannot be the same if the volumes are not.
- D is incorrect as the reaction is 1:1. HNO_3 is monoprotic.

Question 12

Water can be produced from the reaction between hydrogen gas and oxygen gas:

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

What volume of oxygen gas, in L, is required at STP to react with 4.0 g of hydrogen gas?

A. 2
B. **22.4**
C. 32
D. 44.8

Answer is B

Worked solution

- B is correct.

$$n(H_2) = \frac{m}{M} = \frac{4}{2} = 2 \text{ mole}$$

$$n(O_2) = \frac{1}{2} n(H_2) = 1 \text{ mole}$$

1 mole of oxygen has a volume of 22.4 L at STP by definition.

- A is incorrect as it is the number of mole of hydrogen, not the volume of oxygen.
- C is incorrect as it is the mass of oxygen, not the volume.
- D is incorrect. There is only 1 mole of oxygen, once the balanced equation is taken into account

Question 13

In a particular reaction, 1.2 mole of one reactant reacts exactly with 1.8 mole of the other reactant. The equation for the reaction could be

A. $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
B. $\mathbf{2H_3PO_4(aq) + 3Ba(OH)_2(aq) \rightarrow Ba_3(PO_4)_2(aq) + 6H_2O(l)}$
C. $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
D. $2FeCl_2(aq) + Cl_2(g) \rightarrow 2FeCl_3(aq)$

Answer is B

Worked solution

- B is correct. The ratio between 1.2 and 1.8 is 2:3 or 1:1.5. This can be found by dividing both numbers by 1.2.

$$\frac{1.2}{1.2} : \frac{1.8}{1.2} = 1 : 1.5$$

The equation in B has reactants in the ratio 2:3.

- A is incorrect as the reactants are in the ratio 1:1.
- C is incorrect as the reactants are in the ratio 1:1.
- D is incorrect as the reactants are in the ratio 2:1.

Question 14

In the reaction

$Al(s) + 3AgNO_3(aq) \rightarrow Al(NO_3)_3(aq) + 3Ag(s)$

A. aluminium is reduced and silver oxidised
B. **electrons are transferred from aluminium atoms to silver ions**
C. electrons are transferred from silver atoms to aluminium ions
D. protons are donated to the silver ions

Answer is B

Worked solution

- B is correct. The half equations that demonstrate this are:
  $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$
  $Ag^+(aq) + e^- \rightarrow Ag(s)$
- A is incorrect as the aluminium is oxidised.
- C is incorrect as the electrons are moving in the opposite direction.
- D is incorrect and does not hold much relevance. This is not an acid–base reaction.

Tip

It is often easy to start with the metal, rather than metal ions. If aluminium starts off as a metal and ends as an ion, it must be oxidised and lose electrons.

Question 15

Which of the following is a correctly balanced half equation?

A. $Al(s) + 3e^- \rightarrow Al^{3+}(aq)$
B. $Br_2(l) \rightarrow 2Br^-(aq) + 2e^-$
C. $\mathbf{O_2(g) + 4e^- \rightarrow 2O^{2-}(aq)}$
D. $Br_2(l) + e^- \rightarrow 2Br^-(aq)$

Answer is C

Worked solution

- C is correct. When two atoms of oxygen formed two O^{2-} ions, four electrons are required.
- A is incorrect as the electrons are on the wrong side of the half equation.
- B is incorrect as the electrons are on the wrong side of the half equation.
- D is incorrect as two electrons would be needed.

Question 16

In the reaction

$2FeCl_2(aq) + Cl_2(g) \rightarrow 2FeCl_3(aq)$

A. **iron is oxidised and it is the reductant**
B. iron is the oxidant and the reductant
C. iron is reduced and it is the oxidant
D. iron is the reductant and chlorine gas is oxidised

Answer is A

Worked solution

- A is correct. The Fe^{2+} is oxidised to Fe^{3+} and it is acting as the reductant. The change in the iron is evident from the number of chloride ions it is bonded to.
- B is incorrect as iron is the only reductant
- C is incorrect as the iron is oxidised
- D is incorrect; the iron is the reductant but chlorine is not oxidised.

Question 17

When wet corrosion of iron occurs, the reduction half equation is

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

This means that oxygen will
A. react as the anode and have a positive charge
B. not change in oxidation number because it is the water reacting
C. change in oxidation number from –2 to 0
D. **react as the cathode and have a positive charge**

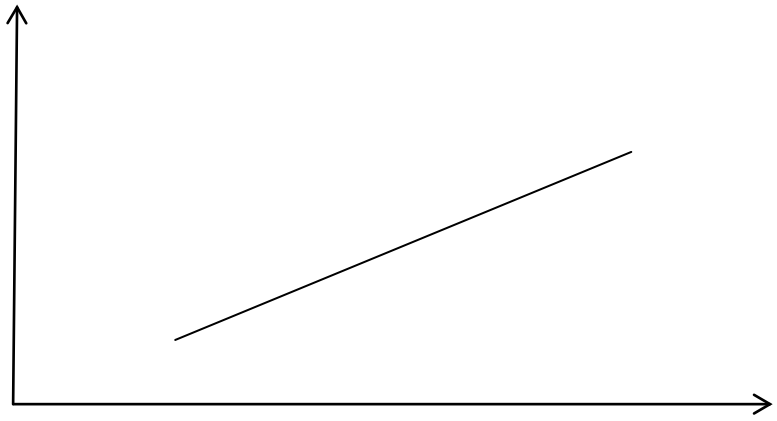
Answer is D

Worked solution

- D is correct. The reaction is reduction and reduction occurs at the cathode. The cathode has a positive charge in a galvanic cell.
- A is incorrect as this is the cathode not the anode.
- B is incorrect as the oxidation number of oxygen does change
- C is incorrect as the oxidation number changes from 0 to –2, not the other way around.

Question 18

An experiment with gases leads to the graph shown.



This could be a graph representing the way the

A. volume of a gas changes with pressure
B. **volume of a gas changes with absolute temperature**
C. volume of a gas changes with temperature, in °C
D. pressure of a gas changes with the volume

Answer is B

Worked solution

- B is correct. The volume of a gas is directly proportional to temperature and the correct unit of temperature is the kelvin.
- A is incorrect as a graph between pressure and volume is a hyperbola because they are inversely proportional.
- C is incorrect. If °C is used, the graph will not pass close to the origin.
- D is incorrect, for the same reason as A.

Question 19

A 400 mL sample of an ideal gas has a pressure of 200 kPa. If the volume of the container is doubled and the temperature is halved, the pressure will now be, in kPa,

A. **50**
B. 100
C. 200
D. 400

Answer is A

Worked solution

- A is correct. If the volume is doubled, the pressure will be halved. If the temperature is halved, the pressure will again be halved. Therefore the pressure is one-quarter of the original value. This is $200 \times \frac{1}{4} = 50$.
- B is incorrect as 50 is the correct answer.
- C is incorrect as 50 is the correct answer.
- D is incorrect as 50 is the correct answer.

Question 20

Ozone gas can be produced in low concentrations in combustion engines such as in a car. The production of ozone in this way is

A. **bad because ozone gas is an irritant to humans**
B. good because there is a hole in the ozone layer over Australia
C. bad because ozone gas is a serious contributor to the Earth's greenhouse gases
D. good because ozone is an allotrope of oxygen gas

Answer is A

Worked solution

- A is correct. Ozone is a pollutant because it is a respiratory irritant. Ozone is useful in a much higher layer of the atmosphere but not at ground level.
- B is incorrect as the ozone needs to be in upper layers of the atmosphere.
- C is incorrect as ozone layer issues are separate from greenhouse issues.
- D is incorrect as ozone is toxic to humans.

Tip

You need to be clear on the difference between 'greenhouse' issues and 'ozone layer' issues.

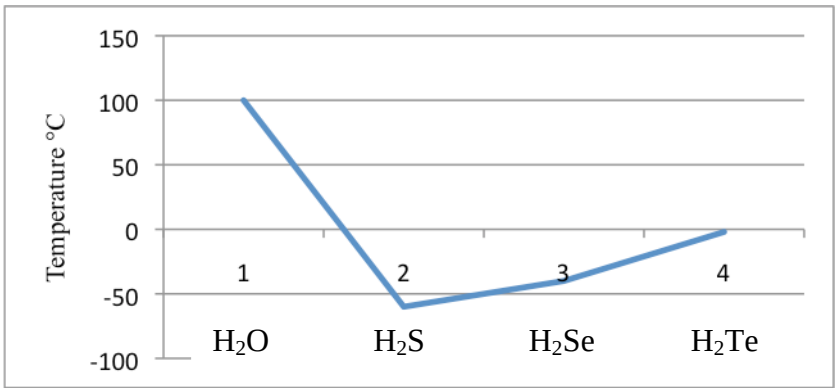
END OF SECTION A

SECTION B – Short-answer questions

Question 1

Water is a covalently bonded molecule with a formula of H_2O. It is essential for the existence of life as we know it. Water is a common chemical but it has some unique properties.

a. The boiling points of the group 16 hydrides are shown in the graph below.



i. Does the boiling point of water follow the trend of the other group 16 hydrides? Use the data supplied to support your answer.

ii. What aspect of the bonding in water causes the graph to have the shape that it does?

2 marks

Solution

i. The boiling point of water is much higher than expected. If you extrapolate the other hydrides, you would expect the boiling point to be as low as –70°C.

ii. The polar nature of the water molecule leads to this unusually high boiling point.
The forces between water molecules are higher than in the other hydrides because of the significant dipoles in water. Strong hydrogen bonds exist.

Mark allocation

i. • 1 mark for explaining that the boiling point of water is not consistent with the other hydrides – it is higher.

ii. • 1 mark for explaining that the high boiling point is a result of hydrogen bonding in the water.

1 + 1 = 2 marks

Explanatory notes
The dipoles in water are significant ones. The difference in electronegativity between hydrogen and oxygen is bigger than in the other hydrides. The impact on the water molecule is that it has stronger hydrogen bonds and a higher boiling point than expected.

Tip

Water has a number of unusual properties. The hydrogen bonding in water is the cause of all of these properties.

b. The specific heat capacities of several common substances are given in the table below.

Substance	**Specific heat capacity (g^{-1} °C^{-1})**
water	4.2
olive oil	2.2
copper	0.44

i. What conclusion about water can you draw from this table?

ii. Two similar beakers are placed on the same hotplate. 50 mL of water is added to the first and 50 mL of ethanol is added to the second. Will the two liquids reach their boiling points after the same period of time? Explain your answer.

3 marks

Solution

i. The specific heat capacity of water is relatively high.

ii. The two beakers will reach their boiling points at quite different times. The boiling points and specific heat capacities differ. Ethanol has a lower specific heat capacity than water; therefore, its temperature will increase at a faster rate. It has a lower boiling point as well.

Mark allocation

i. • 1 mark for pointing out the value for water is relatively high.

ii. • 1 mark for acknowledging the different boiling points of the two liquids.
• 1 mark for pointing out the different specific heat capacities of the two liquids.

1 + 2 = 3 marks

Explanatory notes

i. The specific heat capacity for water of 4.2 J g^{-1} °C^{-1} is much higher than for most metals and higher than for most other liquids. Again, it is the dipoles in water that is the reason for this high value.

ii. Water and ethanol will heat up at different rates because they have different specific heat capacities. Ethanol will heat faster. There is only 1 hydrogen bond between ethanol molecules, but 2 hydrogen bonds between water molecules. As a result, intermolecular bonds are stronger in water. As ethanol has weaker intermolecular bonds than water, it has a lower boiling point. This is a second reason why the ethanol will boil first.

c. The densities of water and ice at 0°C are 0.9999 g cm^{-3} and 0.9168 g cm^{-3} respectively.

i. Which one takes up the greatest volume at 0°C: 50 g of ice or 50 g of water?

ii. A car radiator uses water to cool the engine. Explain why antifreeze is added to the water in the radiator.

2 marks

Solution

i. 50 g of ice has the larger volume.

ii. Antifreeze is added to stop the water turning to ice in the radiator. The addition of antifreeze significantly lowers the freezing point of water. If water did freeze, it would expand and crack the engine.

Mark allocation

- 1 mark for correctly identifying ice as having the greater volume.
- 1 mark for explaining the radiator might crack.

1 + 1 = 2 marks

Explanatory notes

Water is an unusual substance in that it expands when it freezes. The unique structure of ice is the reason for this. If water freezes in a bottle, pipe or radiator, it can expand and crack the material it is in.

d. The latent heat of vaporisation of water is 50 kJ mol^{-1}. Explain what the 'latent heat of vaporisation' is.

1 mark

Solution

The 'latent heat of vaporisation' is the energy required to turn a liquid at its boiling point into a gas.

Mark allocation

- 1 mark for explaining that latent heat of vaporisation is the energy required to turn a liquid at its boiling point into a gas.

Explanatory notes

It requires energy to turn a liquid into a gas. The particles require more energy to break free of each other to form a gas.

Total 8 marks

Question 2

The following list contains a number of different chemical substances:

CH_3COOH NH_3 CH_4 Cl_2 NaCl CO_2 LiOH NH_4^+

Use these substances to complete the table below. The same substance may be used more than once.

weak acid	
strong base	
molecule that ionises in water	
conjugate acid/base pair	
conjugate redox pair	
pollutant gas	

Total 6 marks

Solution

weak acid	CH_3COOH or NH_4^+
strong base	LiOH
molecule that ionises in water	HCl, CH_3COOH or NH_3
conjugate acid/base pair	NH_4^+/NH_3
conjugate redox pair	Cl_2/NaCl (Cl^-)
pollutant gas	CH_4 or CO_2

Mark allocation

- 1 mark for each correct row of the table.

Explanatory notes

weak acid	CH_3COOH or NH_4^+. The other acid, HCl is a strong acid.
strong base	LiOH. The only other base is NH_3 but it is weak base.
molecule that ionises in water	HCl, CH_3COOH or NH_3. All three of these molecular substances will form ions in water.
conjugate acid/base pair	NH_4^+/NH_3. A conjugate pair is an acid and the base it forms.
conjugate redox pair	Cl_2/Cl^-. A conjugate pair is an oxidant and the reductant it forms.
pollutant gas	CH_4 or CO_2. Methane adds to greenhouse issues as does carbon dioxide

Total 6 marks

Tip

NH_4^+ and NH_3 are a conjugate pair. Don't try and show NH_2^- or other variations.

Question 3
A large beaker contains 20 mL of 1.0 M hydrochloric acid, HCl. A further 1980 mL of water is added to the beaker.

a. Write a balanced chemical equation for the reaction occurring between the acid and water.

1 mark

Solution

$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

Mark allocation
- 1 mark for showing correct equation with charges.

Explanatory notes
HCl donates a proton to a molecule of water.

b. Is water acting as an acid, a base or a neutral substance in this reaction? Use Lowry–Bronsted definitions to explain your answer.

1 mark

Solution

The water is acting as a base because it is accepting a proton.

Mark allocation
- 1 mark for explaining that water is a base because it accepts a proton.

Explanatory notes
Water can act as either an acid or a base. In this instance it acts as a base because it accepts a proton to form H_3O^+.
Acid: substance that donates a proton.
Base: substance that accepts a proton.

c. Calculate the concentration of the acid after dilution.

2 marks

Solution

$c_1V_1 = c_2V_2$
$20 \times 1 = c_2 \times 2000\text{mL}$ (total volume is 20 + 1980 = 2000)
$c_2 = 0.01$ M

Mark allocation

- 1 mark for providing the correct formula and volume of 2000mL.
- 1 mark for giving the correct answer.

1 + 1 = 2 marks

Explanatory notes

The question is a standard dilution. As the volume goes from 20 to 2000 mL, the concentration will drop by the same factor of 100. The concentration goes from 1.0 to 0.01 M. The formula $c_1V_1 = c_2V_2$ can be used to determine this answer more formally.

Tip

A volume of '1980' or '990' or '99' given in a question should suggest that the total volume is the bigger, rounded number. In this question, for example, the 20 mL plus the 1980 mL gives a more rounded figure of 2000 mL.

d. **i**. What is the pH of the acid before dilution?

ii. What is the pH of the acid after dilution?

iii. By what factor was the volume changed?

iv. By what factor did the pH change?

4 marks

Solution

i. $c(HCl) = 1.0 \Rightarrow pH = 0$

ii. $c(HCl) = 0.01\ M \Rightarrow pH = 2$

iii. 100

iv. 2

Mark allocation

- 1 mark for each correct answer.

1 + 1 + 1 + 1 = 4 marks

Explanatory notes

i. $c(HCl) = 1.0 \Rightarrow pH = 0$. This is a standard pH calculation.

ii. $c(HCl) = 0.01\ M \Rightarrow pH = 2$

iii. The concentration has gone from 1.0 M to 0.01 M. This is a factor of 100, also evident from the volumes used.

iv. If concentration of acid changes by a factor of 100, pH changes by 2.

Tip

As a consequence of the logarithmic scale used in the pH formula, if concentration changes by a:

- *factor of 10, pH changes by 1*
- *factor of 100, pH changes by 2*
- *factor of 1000, pH changes by 3.*

e. What volume of 0.50 M lithium hydroxide, LiOH, must be added to neutralise the undiluted acid?

2 marks

Solution

$n(HCl) = c \times V = 0.02$ mol
$n(LiOH) = n(HCl) = 0.02$ mol

$V = \frac{n}{c} = \frac{0.02}{0.5} = 0.04$ L

Mark allocation

- 1 mark for calculating $n(HCl)$.
- 1 mark for calculating the volume of LiOH.

1 + 1 = 2 marks

Explanatory notes

The calculation is a titration one. The number of mole of HCl is 0.02, so $n(LiOH)$ will be the same. It does not make any difference whether the calculation is done from the solution before or after the dilution

Total 10 marks

Question 4

Aluminium metal will react slowly in hydrochloric acid. The equation for the reaction is:

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

A 10.0 g piece of aluminium is added to a beaker containing 2.00 M hydrochloric acid.

a. Calculate the minimum volume of hydrochloric acid required to react with this aluminium.

3 marks

Solution

$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

$n(Al) = \frac{10}{27} = 0.37$ mol

$n(HCl) = 3 \times n(Al) = 3 \times 0.37 = 1.11$ mol

$V(HCl) = \frac{n}{c} = \frac{1.11}{2} = 0.556$ L

Mark allocation

- 1 mark for calculating $n(Al)$.
- 1 mark for calculating $n(HCl)$.
- 1 mark for correct final volume.

1 + 1 + 1 = 3 marks

Explanatory notes

This is a standard stoichiometry calculation. Calculate the number of mole of aluminium, then multiply it by three because the ratio in the equation is 2:6 or 1:3. The HCl is a solution so the volume is calculated using *V=n/c.*

Tip

- *This is a standard stoichiometry question.*
- *If a mass is given,* $n = \frac{m}{M}$ *will probably be used.*
- *If a concentration is given,* $n = c \times V$ *will probably be used.*

b. Calculate the theoretical mass of aluminium chloride that will be formed in this reaction.

2 marks

$n(AlCl_3) = n(Al) = 0.37$ mol
mass$(AlCl_3) = n \times M = 0.37 \times (27 + 3 \times 35.5) = 49.4$ g

Mark allocation
- 1 mark for calculating $n(AlCl_3)$.
- 1 mark for correct mass calculation.

1 + 1 = 2 marks

Explanatory notes
$n(AlCl_3)$ is the same as for the aluminium because they have the same coefficient in the equation.
Use $n = \frac{m}{M}$ to calculate the mass of the $AlCl_3$.

c. What volume of hydrogen gas will be produced if the temperature is 20.0°C and the pressure is 108 kPa?

3 marks

Solution

$n(H_2) = \frac{1}{2} n(HCl) = \frac{1}{2} \times 1.11 = 0.556$ mol

$V = \frac{nRT}{P} = \frac{0.556 \times 8.31 \times 293}{108} = 12.5$ L

Mark allocation
- 1 mark for calculating $n(H_2)$.
- 1 mark for using correct units for temperature and pressure.
- 1 mark for correct answer.

1 + 1 + 1 = 3 marks

Explanatory notes
The number of moles of hydrogen is half that of HCl as the ratio of coefficients in the equation is 3:6 or 1:2. Since hydrogen is a gas, the volume is calculated using $V = \frac{nRT}{P}$.
Correct units of pressure, kPa, and temperature, K, need to be used.

Total 8 marks

Tip
- *Make sure you know what units to use with the formula PV = nRT.*
- *R will have a value of 8.31, if P is in kPa, V is in L and T is in K.*

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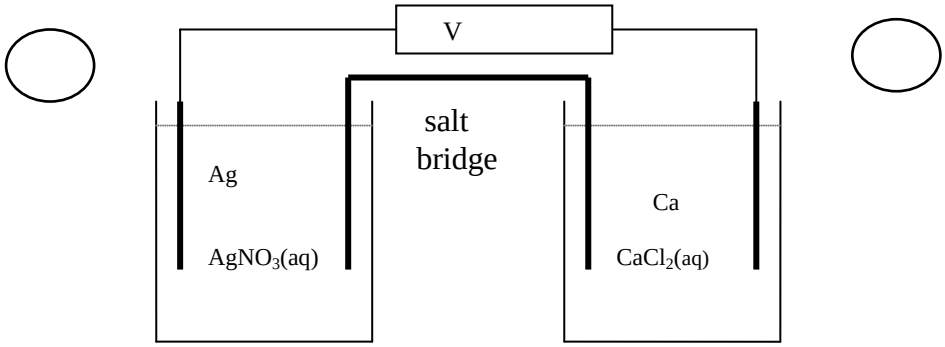
Question 5

A galvanic cell can be formed when a silver half-cell is connected to a calcium half-cell. The cell is drawn below.



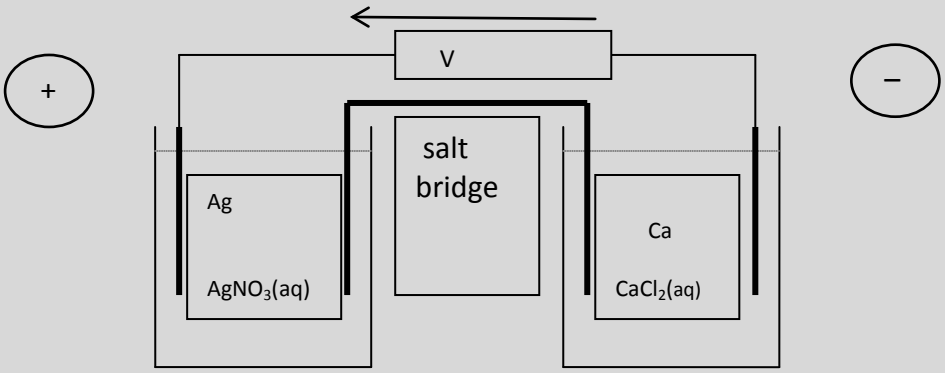
Half-equations: _____ _____

a. **i**. Use the lines provided to write in the half-equations for the reactions occurring in each half-cell

ii. Write a balanced overall equation for the reaction occurring in this cell.

2 + 1 = 3 marks

Solution



Half-equations: $Ag^+(aq) + e^- \rightarrow Ag(s)$ $\quad$ $Ca(s) \rightarrow Ca^{2+}(aq) + 2e^-$

i. See cell above.

ii. $2Ag^+(aq) + Ca(s) \rightarrow 2Ag(s) + Ca^{2+}(aq)$

Mark allocation

- 1 mark for each correct half-equation.
- 1 mark for the overall equation. (It is acceptable to include spectator ions.)

2 + 1 = 3 marks

Explanatory notes

The electrochemical series shows that calcium will react with silver ions. This is also predicted from a knowledge of metals and their reactivity – calcium is more reactive than silver so it can replace silver ions in solution. The two half-equations are given on the electrochemical series.

Two silver ions react with each calcium atom for the electrons to be balanced.

Tip

It is an expectation that you can draw up any cell if the reactants are on the electrochemical series. The fact that the half-equations are provided for you, and that they are in order, takes all the guesswork out of drawing the cell and determining the polarity of the electrodes.

b. Use the circles provided to show the polarity of each electrode.

1 mark

Solution

Silver is positive; calcium is negative.

Mark allocation

- 1 mark for identifying polarity correctly.

Explanatory notes

Silver undergoes reduction. Reduction occurs at the cathode and the cathode is positive in galvanic cells.

c. Use an arrow to show the direction of electron flow in the cell.

1 mark

Solution

See diagram. Electrons flow from the negative electrode to the positive electrode.

Mark allocation

- 1 mark for identifying correct direction of flow.

Explanatory notes

When calcium is oxidised, it releases electrons. The electrons flow to the positive electrode.

Tip

In galvanic cells, if metals are involved, the least reactive metal will always be the positive electrode. Remembering this often saves time working it out from first principles.

d. **i**. What will happen to the calcium electrode as the cell discharges?

ii. What will happen to the silver electrode as the cell discharges?

1 + 1 = 2 marks

Solution

i. The calcium electrode will gradually disappear as it converts to calcium ions.

ii. The silver electrode will increase in size as more silver deposits on it.

Mark allocation

- 1 mark for correct description of the change to each electrode.

1 + 1 = 2 marks

Explanatory notes

The half-equations and states of the products can tell you what happens at the electrodes. If Ca^{2+} ions are forming, the calcium electrode will be shrinking.
If Ag(s) is forming, the silver electrode will be growing in size.

Total 7 marks

Question 6

A sample of carbon dioxide gas can be prepared in the laboratory by heating calcium carbonate, $CaCO_3$.

a. Write a balanced equation for the production of carbon dioxide from the heating of calcium carbonate.

1 mark

Solution

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Mark allocation

- 1 mark for correct equation as shown.

1 mark

Explanatory notes

Calcium carbonate decomposes to CaO, releasing carbon dioxide gas.

b. **i**. Describe how you would capture a sample of the gas.

ii. A glowing splint is lowered into a sample of carbon dioxide. What would you expect to happen?

iii. List three properties of carbon dioxide.

2 + 1 + 1 = 4 marks

Solution

i. Heat the calcium carbonate in a test tube with a single-holed stopper. Collect the gas by downward delivery, not by displacement of water. The mild solubility of the carbon dioxide makes displacement of water unsatisfactory and the density of the gas lends itself to downward delivery.

ii. The glowing splint will extinguish fairly quickly. Carbon dioxide is used to extinguish fires; it does not support combustion or go pop.

iii. Carbon dioxide is slightly soluble in water, colourless, odourless and dense and does not support combustion.

Mark allocation

i.
- 1 mark for describing the use of a test tube and tubing.
- 1 mark for choice of downward delivery. An explanation about the density of carbon dioxide determining the technique to use, is worth a mark if you have not already attained 2 marks.

ii.
- 1 mark for explaining that the glowing splint will be extinguished.

iii.
- 1 mark for any three of the properties mentioned.

2 + 1 + 1 = 4 marks

Explanatory notes

When calcium carbonate is heated, carbon dioxide is released. The equipment chosen for the experiment needs to allow you to capture this gas. A test tube or flask with a single-holed stopper and tubing will do this. Carbon dioxide gas is denser than air, so it can be allowed to enter the bottom of a gas jar and displace the air in the jar until a sample is obtained. It can be collected under water but a significant amount is lost when it dissolves in the water.

Carbon dioxide smothers fires by preventing oxygen getting to the site of combustion. The glowing splint should go out.

Carbon dioxide is colourless and odourless. It dissolves in water to form carbonic acid. It is a relatively heavy gas as evidenced by its use in theatre productions.

c. **i**. Carbon dioxide is considered a greenhouse gas. Explain how increasing levels of carbon dioxide in the Earth's atmosphere are expected to impact upon our climate.

ii. List two significant sources in society of carbon dioxide emissions.

2 + 2 = 4 marks

Solution

i. Carbon dioxide in the atmosphere helps stop heat from the Earth's surface escaping back to space. The Earth might be warmer than expected, causing climate issues.

ii. Burning of coal for electricity; combustion of petrol or LPG in cars. Respiration in animals.

Mark allocation

i.
- 1 mark for explaining that heat is trapped in the Earth's atmosphere.
- 1 mark for explaining that the higher temperatures will impact on climate. Be careful not to confuse ozone layer issues with greenhouse issues.

ii.
- 1 mark for each correct alternative. Many possible fuels could be mentioned.

2 + 2 = 4 marks

Explanatory notes

Emissions of carbon dioxide are leading to higher levels of carbon dioxide in the Earth's atmosphere than ever before. Carbon dioxide blocks the escape of heat from the Earth's surface because it reflects some of the heat back. The general temperatures in most parts of the world are considered to be rising. This will cause a shift in rainfall patterns and increase the likelihood of unseasonal extremes.

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d. A sample of carbon dioxide is collected in a gas jar. The gas jar is left on a bench in a laboratory for several hours at a constant temperature. Describe the motion of the particles in the gas sample.

3 marks

Solution

The particles move rapidly, colliding frequently with each other and with the sides of the container. Collisions are elastic and the particles move in straight lines between collisions.

Mark allocation

- 1 mark for particles moving in straight lines.
- 1 mark for elastic collisions.
- 1 mark for frequent collisions with each other and the sides of the container.

3 marks

Explanatory notes

This question is checking your knowledge of the kinetic theory postulates for gases. The fact that the question refers to carbon dioxide is coincidental as the answer would be the same for any ideal gas. The fact that the container is left to sit does not affect your answer either.

Total 12 marks

Question 7

Iron corrodes when it reacts with oxygen. The corrosion rate is usually faster under wet conditions.

a. **i**. Write a half-equation for the initial reaction of iron when it corrodes.

ii. Will the corroding iron be the anode or the cathode?

1 + 1 = 2 marks

Solution

i. $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

ii. This is oxidation, which will happen at the anode.

Mark allocation

i. • 1 mark for correct equation as shown.

ii. • 1 mark for identifying the anode.

1 + 1 = 2 marks

Explanatory notes

i. The initial reaction of the iron is to form Fe^{2+}. This might eventually form Fe^{3+}.

ii. Oxidation is at the anode and the anode is the negative electrode. It is oxidation because the oxidation state of the iron has increased.

Tip

Wet corrosion is a complex process to try and work out in an exam. You probably need to learn it off by heart.

b. When an object made from iron is 'galvanised', it is coated in a thin layer of zinc. Explain how galvanising acts to protect iron from corrosion.

2 marks

Solution

Zinc is more reactive than iron. The zinc corrodes before the iron does and protects the iron. The zinc oxide formed often protects the iron as well as the zinc itself did.

Mark allocation

- 1 mark for listing zinc as more reactive than iron.
- 1 mark for explaining that zinc reacts first, providing a coating for the iron.

1 + 1 = 2 marks

Explanatory notes

Zinc is a 'sacrificial' metal. It is more reactive than iron, so it reacts with oxygen instead of iron. The product of the reaction is zinc oxide. The oxide itself forms a protective layer on the iron.

c. Copper does not protect iron from corroding in the same way that zinc does. Explain how it can be predicted whether a particular metal can protect iron from corrosion.

3 marks

Solution

Copper is less reactive than iron so it does not protect the iron. Only metals more reactive than iron will protect iron, but they cannot be too reactive.

Mark allocation

- 1 mark for stating copper is less reactive than iron.
- 1 mark for explaining that the metal used must be more reactive than iron and hopefully form a protective layer.
- 1 mark for referring to the relative reactivity of metals.

1 + 1 + 1 = 3 marks

Explanatory notes

Metals more reactive than iron have to be chosen. The metals must also be relatively cheap and they must not be too reactive or they will not last long. The fact that zinc forms a strong layer of zinc oxide makes it an obvious choice.

Total 7 marks

END OF SOLUTIONS BOOK