INSIGHT

Trial Exam Paper

YEAR 11 CHEMISTRY

Written examination 2

Solutions book

This book presents:

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

SECTION A – Multiple-choice questions

Question 1

Water expands on freezing. This is because

A. water molecules are polar and all polar molecules expand on freezing.

B. the intramolecular bonds of each water molecule lengthen as water cools.

C. water self-ionises more as it cools and the ions formed are larger than water molecules.

D. **each water molecule forms bonds with four other water molecules when in the solid state.**

Answer is D.

Explanatory notes

- D is correct because each water molecule forms hydrogen bonds to four other water molecules in a fixed arrangement when liquid water is cooled to form the solid ice lattice.
- A is incorrect because water is unique in that it expands on freezing. Other polar molecules do not expand on freezing.
- B is incorrect because the covalent intramolecular bonds in a water molecule do not change in length as water cools.
- C is incorrect because the self-ionisation of water is an endothermic process and so would decrease on cooling – not increase. Also, the ions formed are not larger than water molecules.

Question 2

Which of the equations below best represents sodium nitrate dissolving in water?

A. $NaNO_3(s) + H_2O(l) \rightarrow NaNO_3(aq)$

B. $NaNO_3(s) \xrightarrow{H_2O(l)} NaNO_3(l)$

C. $\mathbf{NaNO_3(s) \xrightarrow{H_2O(l)} Na^+(aq) + NO_3^-(aq)}$

D. $2NaNO_3(s) + H_2O(l) \rightarrow 2Na^+(aq) + 2HNO_3(aq)$

Answer is C.

Explanatory notes

- C is correct because sodium nitrate is an ionic substance. Attraction to the polar water molecules causes the ions in the solid lattice to dissociate from one another and become hydrated. The state of sodium nitrate changes from solid to aqueous.
- A is incorrect because water does not actually react with ionic substances when they dissolve.
- B is incorrect because the state of dissolved sodium nitrate is aqueous (aq), not liquid (l).
- D is incorrect because water does not actually react with ionic substances when they dissolve. Also, this equation is unbalanced.

Question 3

Which of the following steps is **not** part of the usual treatment of rainwater in preparation for human consumption?

A. flocculation

B. **distillation**

C. chlorination

D. filtration

Answer is B.

Explanatory notes

- B is correct because distillation is not part of the usual treatment of rainwater. Distillation is a thermal method more often used to remove salt and other minerals from water.
- A is incorrect because flocculation is the process when the addition of alum produces a jelly-like 'floc' which entraps other particles, removes colour and some micro-organisms.
- C is incorrect because gaseous chlorine is added to react with water and produce HOCl, which then kills bacteria.
- D is incorrect because filtration of water through sand and gravel removes any suspended matter remaining after the settling of floc.

Question 4

Which of the following 1.0 M solutions would have the lowest pH?

A. **sulfuric acid**

B. sodium hydroxide

C. ethanoic acid

D. hydrochloric acid

Answer is A.

Explanatory notes

- A is correct because sulfuric acid is a strong, diprotic acid, so would have the greatest concentration of H_3O^+ ions and, hence, the lowest pH.
- B is incorrect because sodium hydroxide is a base, so would have a pH above 7.
- C is incorrect because ethanoic acid is a weak acid, meaning it does not readily donate protons and does not completely ionise in water. 1.0 M of a weak acid will produce fewer H_3O^+ ions than 1.0 M of a strong acid.
- D is incorrect because although hydrochloric acid is a strong acid, it is monoprotic, meaning it has only one proton per molecule to donate to water. 1.0 M of a strong monoprotic acid will produce fewer H_3O^+ ions than 1.0 M of a strong diprotic acid.

Question 5

Which of the following substances is both diprotic and amphiprotic?

A. H_2SO_4

B. **H_2PO4^-**

C. HCO_3^-

D. CH_3COO^-

Answer is B.

Explanatory notes

- B is correct because $H_2PO_4^-$ is diprotic, meaning it has two protons that it is able to donate, and amphiprotic, meaning it is able to act as an acid or a base.
- A is incorrect because although H_2SO_4 is diprotic, it is not amphiprotic. It can act only as an acid.
- C is incorrect because although HCO_3^- is amphiprotic, it is not diprotic because it has only one proton available to donate.
- D is incorrect because CH_3COO^- is neither amphiprotic nor diprotic. It can act only as an acid and has only one proton to donate.

Question 6

The mass of anhydrous $CuSO_4$, in g, required to be dissolved in water to make 750 mL of 0.250 M solution is closest to

A. 0.188

B. 21.0

C. **30.0**

D. 53.2

Answer is C.

Explanatory notes

- C is correct according to the steps below.

Step 1: Calculate the amount, in mol, of $CuSO_4$ required.

$n(CuSO_4) = c \times V$
$= 0.250 \times 0.750$
$= 0.188$ mol

Step 2: Calculate the mass, in grams, of $CuSO_4$ required.

$m(CuSO_4) = n \times M$
$= 0.188 \times (63.6 + 32.1 + (4 \times 16.0))$
$= 0.188 \times 159.7$
$= 30.0$ g

- A is incorrect because 0.188 is the amount, in mol, of $CuSO_4$ required and must be converted to mass, using $m = n \times M$.
- B is incorrect because the molar mass of $CuSO_4$ is 159.7, not 111.7. There are four oxygen atoms contributing to the molar mass of this formula.
- D is incorrect because $n(CuSO_4) = c \times V$, not $\frac{c}{V}$.

Question 7

The pH of a 0.100 M solution of $Ca(OH)_2$ is closest to

A. 0.699

B. 1.00

C. 13.0

D. **13.3**

Answer is D.

Explanatory notes

- D is correct according to the steps below.
  Step 1: Determine the $[OH^-]$ in solution.

  Each $Ca(OH)_2$ molecule produces two OH^- ions, so $[OH^-] = 2 \times c(Ca(OH)_2) = 0.200$ M

  Step 2: Determine the $[H_3O^+]$ in solution.

  $$[H_3O^+] = \frac{10^{-14}}{[OH^-]}$$

  $$= \frac{10^{-14}}{0.200}$$

  $$= 5.00 \times 10^{-14} \text{ M}$$

  Step 3: Determine the pH.

  $pH = -\log_{10}[H_3O^+]$

  $= -\log_{10}(5.0 \times 10^{-14})$

  $= 13.3$
- A is incorrect because $Ca(OH)_2$ is a base, not an acid.
- B is incorrect because $Ca(OH)_2$ is a base, not an acid. Also, each $Ca(OH)_2$ molecule produces two OH^- ions, so $[OH^-] = 2 \times c(Ca(OH)_2) = 0.200$ M.
- C is incorrect because each $Ca(OH)_2$ molecule produces two OH^- ions, so $[OH^-] = 2 \times c(Ca(OH)_2) = 0.200$ M.

Question 8

An amount of 1.78 g of Mg reacts with 100 mL of 1.0 M HCl according to the equation

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The mass of H_2 gas formed, in grams, is closest to

A. 0.100

B. 0.147

C. 0.200

D. 0.400

Answer is A.

Explanatory notes

- A is correct according to the steps below.
  Step 1: Determine the amount, in mol, of both reactants.

  $n(\text{Mg}) = \frac{m}{M}$ $\qquad$ $n(\text{HCl}) = cV$

  $= \frac{1.78}{24.3}$ $\qquad$ $= 0.1 \times 1.0$

  $= 0.0733$ mol $\qquad$ $= 0.100$ mol

  Step 2: Determine which is the limiting reactant by dividing the amount of each by its coefficient in the chemical equation.

  Mg: $\frac{0.0733}{1}$ $\qquad$ HCl: $\frac{0.100}{2}$

  $= 0.0733$ $\qquad$ $= 0.0500$

  HCl has the lowest value, so is the limiting reactant.

  Step 3: Determine the amount, in mol, of H_2 gas formed using the mole ratio in the equation and the amount, in mol, of the limiting reactant.

  $n(H_2) : n(\text{HCl})$

  1 : 2

  So, $n(H_2) = \frac{1}{2} \times 0.100$

  $= 0.0500$ mol

  Step 4: Determine the mass of H_2 gas formed.

  $m(H_2) = n \times M$

  $= 0.0500 \times 2.0$

  $= 0.100$ g

- B is incorrect because Mg is in excess. HCl is the limiting reactant and so must be used to correctly predict the amount of product formed.
- C is incorrect because the ratio $n(H_2) : n(\text{HCl})$ is 1 : 2, not 1 : 1.
- D is incorrect because the ratio $n(H_2) : n(\text{HCl})$ is 1 : 2, not 2 : 1.

Question 9

Which species is acting as the reductant in the reaction represented by the equation below?

$$4Fe^{2+}(aq) + O_2(g) + 4H^+(aq) \rightarrow 4Fe^{3+}(aq) + 2H_2O(l)$$

A. **Fe^{2+}**

B. O_2

C. H^+

D. Fe^{3+}

Answer is A.

Explanatory notes

- A is correct because the reductant is the species that causes another species to be reduced and is itself oxidised. Oxidation is the loss of electrons. Fe^{2+} loses one electron to form Fe^{3+} and so is the reductant.
- B is incorrect because O_2 undergoes reduction and so is the oxidant in this reaction.
- C is incorrect because H^+ is neither oxidised nor reduced in this reaction.
- D is incorrect because Fe^{3+} is a product. It is acting as neither the oxidant nor the reductant. Also, Fe^{3+} is able to undergo reduction only, so could only ever act as an oxidant.

Question 10

Which of the following is most likely to oxidise $Br^-(aq)$?

A. $Ag^+(aq)$

B. **Au^+ (aq)**

C. $Fe^{3+}(aq)$

D. $I^-(aq)$

Answer is B.

Explanatory notes

- B is correct because $Au^+(aq)$ is an oxidant that is higher in the electrochemical series than $Br^-(aq)$, which is a reductant.
- A is incorrect because although $Ag^+(aq)$ is an oxidant, it is lower in the electrochemical series than $Br^-(aq)$, so they will not spontaneously react with each other.
- C is incorrect because although $Fe^{3+}(aq)$ is an oxidant, it is lower in the electrochemical series than $Br^-(aq)$, so they will not spontaneously react with each other.
- D is incorrect because both $Br^-(aq)$ and $I^-(aq)$ are reductants, so they will not react with each other.

Question 11

Which one of the following is an effect of ozone depletion?

A. increased ultraviolet light reaching the Earth

B. increased acid rain

C. increased photochemical smog

D. increased global warming

Answer is A.

Explanatory notes

- A is correct because ozone in the stratosphere absorbs ultraviolet light from the Sun, preventing it from reaching the Earth.
- B is incorrect because acid rain forms when water vapour combines with different gases in the atmosphere, such as SO_2 and SO_3.
- C is incorrect because photochemical smog forms from the action of sunlight on a mixture of gases in the atmosphere, not including ozone.
- D is incorrect because global warming is caused by the enhanced greenhouse effect, which is caused by increasing levels of greenhouse gases in the atmosphere. Ozone is not a greenhouse gas.

Question 12

In the process of denitrification in the nitrogen cycle

A. plants return nitrogen to the atmosphere.

B. bacteria in the soil convert nitrogen in the atmosphere to soluble ions.

C. soluble ions are converted to proteins in plants.

D. bacteria in the soil return nitrogen to the atmosphere.

Answer is D.

Explanatory notes

- D is correct.
- A is incorrect because plants do not return nitrogen to the atmosphere. Rather, the remains of dead plants and excreted waste from animals that have eaten the plants are returned to the soil where bacteria carry out the process of denitrification.
- B is incorrect because this process is nitrogen fixation, not denitrification.
- C is incorrect because this process is not denitrification.

Question 13

Which of the following statements about kinetic molecular theory best explains why an inflated tractor tyre remains inflated over time?

A. Collisions between particles are elastic.

B. Most of the volume of a gas is empty space.

C. Forces between gas particles are extremely weak.

D. Gas particles move in random straight-line motion.

Answer is A.

Explanatory notes

- A is correct because the elastic collisions ensure the gas particles do not lose energy over time, so the tractor tyre remains inflated.
- B is incorrect because although most of the volume of a gas being empty space explains why tyres can be compressed, it does not explain why they remain inflated.
- C is incorrect because although the forces between gas particles being extremely weak explains why gases expand to fill the tyre, it does not explain why the tyre remains inflated.
- D is incorrect because although gas particles moving in random straight-line motion explains why strong smells quickly spread, it does not explain why a tyre remains inflated.

Question 14

A container of oxygen has a volume of 35.0 mL and a pressure of 5.00 atm. If the pressure of the oxygen gas is reduced to 2.00 atm and the temperature is kept constant, the new volume of the oxygen gas, in mL, will be

A. 14.0

B. 35.0

C. 87.5

D. 105

Answer is C.

Explanatory notes

- C is correct according to the following use of Boyle's law.

  $P_1V_1 = P_2V_2$

  $5.00 \times 35.0 = 2.00 \times V_2$

  $$V_2 = \frac{5.00 \times 35.0}{2.00}$$

  $= 87.5$ mL
- A is incorrect because Boyle's law shows that $P_1V_1 = P_2V_2$; that is, the volume of a fixed amount of gas at constant temperature is inversely proportional to its pressure, not directly proportional.
- B is incorrect because the volume of a fixed amount of gas at constant temperature is inversely proportional to its pressure.
- D is incorrect because Boyle's law shows that $P_1V_1 = P_2V_2$; that is, the volume of a fixed amount of gas at constant temperature is inversely proportional to its pressure.

Question 15

A balloon has a volume of 2.80 L on a day when the temperature is 32.0°C. If the temperature at night falls to 15.0°C, the volume of the balloon at night, in L, if the pressure remains constant will be

A. 1.31

B. **2.64**

C. 2.80

D. 2.97

Answer is B.

Explanatory notes

- B is correct according to the following use of Charles' law.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{2.80}{(32.0 + 273)} = \frac{V_2}{(15.0 + 273)}$$

$$V_2 = \frac{2.80}{305} \times 288$$

$$= 2.64 \text{ L}$$

- A is incorrect because for use in any gas equations, the temperatures must be expressed in Kelvin, not °C.
- C is incorrect because the volume of a fixed amount of gas at constant pressure is directly proportional to its temperature in Kelvin.
- D is incorrect because Charles' law shows that the volume of a fixed gas at constant pressure is directly proportional to the temperature in Kelvin, not inversely proportional.

Question 16

A sample of oxygen gas collected over water, when the atmospheric pressure was 1.02 atm and the room temperature 25.5°C, occupies 105.8 mL. What would be the volume of this dry gas, in mL, at STP?

A. 4.23

B. **98.7**

C. 108

D. 118

Answer is B.

Explanatory notes

- B is correct according to the following use of the combined gas equation. STP conditions are 0°C and 1.00 atm pressure.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.02 \times 105.8}{(25.5 + 273)} = \frac{1.00 \times V_2}{(0 + 273)}$$

$$\frac{V_2 \times 1.00}{273} = \frac{107.9}{298.5}$$

$$V_2 = 98.7 \text{ mL}$$

- A is incorrect because the temperatures must be expressed in Kelvin, not °C.
- C is incorrect because STP conditions are 0°C and 1.00 atm pressure. It is the SLC conditions that are 25°C and 1.00 atm.
- D is incorrect because $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, not $P_1V_1T_1 = P_2V_2T_2$.

Question 17

At what pressure, in kPa, would 15.0 g of nitrogen gas at 18.0°C occupy 12.5 L?

A. 9.64×10^{-3}

B. 6.41

C. **104**

D. 208

Answer is C.

Explanatory notes

- C is correct according to the steps below.

  Step 1: Determine the amount, in mol, of nitrogen gas.

  $n(N_2) = \frac{m}{M}$

  $= \frac{15.0}{2 \times 14.0}$

  = 0.536 mol

  Step 2: Determine the pressure, using the general gas equation.

  PV = nRT

  $P = \frac{nRT}{V}$

  $= \frac{0.536 \times 8.31 \times (18.0 + 273)}{12.5}$

  $= \frac{1296.2}{12.5}$

  = 104 kPa

- A is incorrect because $P = \frac{nRT}{V}$, not $\frac{V}{nRT}$.
- B is incorrect because temperature needs to be converted to Kelvin for use in the general gas equation.
- D is incorrect because the molecular formula of nitrogen gas is N_2, so its molar mass is 28.0 $gmol^{-1}$, not 14.0 $gmol^{-1}$.

Question 18

Which of the following gases will occupy the biggest volume at SLC?

A. 5.0 g of CO_2

B. 5.0 g of NO_2

C. 5.0 g of SO_2

D. **5.0 g of O_2**

Answer is D.

Explanatory notes

- D is correct because O_2 has the smallest molar mass, so represents the largest number of mole for 5.0 g of mass. The same amount of different gases occupies the same volume under the same conditions, so 5.0 g of O_2 with the biggest amount, in mol, will occupy the biggest volume. The volume occupied can be calculated:

$$n(O_2) = \frac{m}{M}$$

$$= \frac{5.0}{2 \times 16.0}$$

$$= 0.156 \text{ mol}$$

$$V(O_2) = n \times V_M$$

$$= 0.156 \times 24.5$$

$$= 3.83 \text{ L}$$

- A is incorrect because the volume of 5.0 g of CO_2 at SLC is 2.78 L, which is less than the volume occupied by 5.0 g of O_2.
- B is incorrect because the volume of 5.0 g of NO_2 at SLC is 2.66 L, which is less than the volume occupied by 5.0 g of O_2.
- C is incorrect because the volume of 5.0 g of SO_2 at SLC is 1.91 L, which is less than the volume occupied by 5.0 g of O_2.

Question 19

Which of the following gases is **not** a contributor to photochemical smog?

A. **carbon dioxide**

B. nitrogen oxides

C. hydrocarbons

D. oxygen

Answer is A.

Explanatory notes

- A is correct because although carbon dioxide is a greenhouse gas, it does **not** contribute to photochemical smog.
- B, C and D are incorrect because nitrogen oxides, hydrocarbons and oxygen are all contributors to photochemical smog.

Question 20

What volume, in mL, of 0.150 M sulfuric acid is required to react completely with 15.0 mL of 0.100 M sodium hydroxide?

A. **5.00**

B. 10.0

C. 15.0

D. 20.0

Answer is A.

Explanatory notes

- A is correct according to the steps below.

  Step 1: Write a balanced chemical equation for the reaction.

  $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

  Step 2: Determine the amount, in mol, of sodium hydroxide**.**

  $n(NaOH) = cV$

  $= 0.100 \times 0.0150$

  $= 0.001\,50$ mol

  Step 3: Use the mole ratio in the equation to determine the amount, in mol, of sulfuric acid required.

  $n(H_2SO_4) : n(NaOH)$

  1 : 2

  So, $n(H_2SO_4) = \frac{1}{2} \times n(NaOH)$

  $= \frac{1}{2} \times 0.001\,50$

  $= 7.50 \times 10^{-4}$ mol

  Step 4: Determine the volume of 0.150 M sulfuric acid required.

  $V(H_2SO_4) = \frac{n}{c}$

  $= \frac{7.50 \times 10^{-4}}{0.150}$

  $= 0.005\,00$ L

  $= 5.00$ mL

- B is incorrect because the mole ratio of $n(H_2SO_4) : n(NaOH)$ is 1 : 2, not 1 : 1.
- C is incorrect because the substances are present in different concentrations and do not react with a 1 : 1 ratio, so require different volumes for complete reaction.
- D is incorrect because they react in the ratio $n(H_2SO_4) : n(NaOH) = 1 : 2$, not 2 : 1.

END OF SECTION A

SECTION B – Short-answer questions

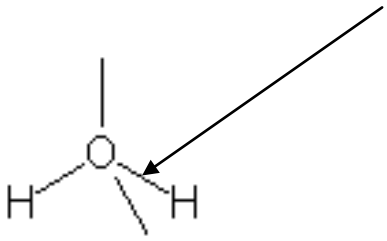
Question 1

Water is an abundant chemical in the environment where it supports life in many ways.

a. i. Draw the structure of a water molecule in the space below, demonstrating the correct shape and including all non-bonding electrons.

ii. On your diagram above, clearly label and name the intramolecular bond present.

Solution



1 + 1 = 2 marks

Mark allocation

- 1 mark for the structure. It must be shown in the correct bent/V-shape and include non-bonding electron pairs, which can be shown as a single line or pair of dots.
- 1 mark for correct label and name of covalent bond.

b. Briefly explain why water is a polar molecule.

Solution

Water is a polar molecule because its bonds are polarised and are distributed asymmetrically across the molecule therefore bond dipoles do not cancel out; that is, molecule has a partial negative end and a partial positive end.

2 marks

Mark allocation

- 1 mark for polarised bonds/bond dipoles.
- 1 mark for bond dipoles do not cancel out/partial negative end and partial positive end.

Explanatory notes

The O–H bond is polarised because oxygen has a greater electronegativity than hydrogen, meaning it gains a greater share of the electron pair and carries a partial negative charge. The hydrogen atoms carry a positive partial charge. If the partial charges are distributed asymmetrically across the molecule, the bond dipoles do not cancel, and it is said to be polar.

Tip

- *This question is worth 2 marks, indicating the answer is likely to require two key points.*

c. What is the name of the strongest type of bonding that occurs between different water molecules?

Solution

hydrogen bonding

1 mark

Explanatory notes

Hydrogen bonding occurs between molecules that are polar and have a H atom bonded to a N, O or F atom. The bond occurs between the partially positive H atom on one water molecule and the lone pair of electrons on the O atom on another water molecule.

d. Give a brief explanation of each of the following properties of water.

i. Water has a relatively high boiling temperature.

Solution

The relatively strong hydrogen bonds can absorb large amounts of energy before the bond breaks and the water molecules separate.

ii. Water is a poor conductor of electricity**.**

Solution

Water self-ionises, generating a small number of H_3O^+ and OH^- ions which are always present in pure water.

1 + 1 = 2 marks

Explanatory notes

The ability to conduct electricity requires the presence of mobile charged particles. In water the charged particles are the ions formed when water reacts with itself according to

$H_2O(l) + H_2O(l) \rightarrow H_3O^+(aq)$ and $OH^-(aq)$. These ions are free to move around in solution.

Total 2 + 2 + 1 + 2 = 7 marks

Question 2

A small mass of potassium chloride is dissolved in water.

a. Name the type of bonds that need to be broken in the solute during this process.

Solution

ionic

1 mark

Explanatory notes

Potassium is a metal element and chlorine is a non-metal element, so when they combine they form an ionic substance in which the bonding is ionic.

b. Name the type of bonds that are formed between the solute and water during this process.

Solution

ion-dipole

1 mark

Explanatory notes

Ion-dipole interactions occur between dissociated potassium and chloride ions and polar water molecules. The K^+ ions are attracted to the negative partial charge on the O atoms in water and the Cl^- ions are attracted to the partially positive H atoms.

c. Describe the way in which this dissolving process occurs.

Solution

Attraction to the polar water molecules causes the potassium and chloride ions in the ionic lattice to dissociate from each other and become hydrated (i.e. surrounded by water molecules).

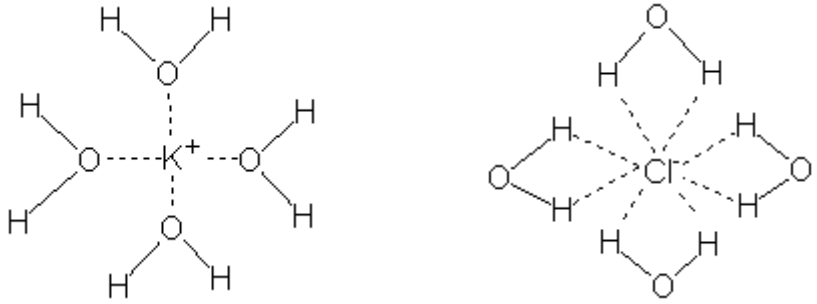
2 marks

Mark allocation

- 1 mark for attraction to water molecules causes dissociation.
- 1 mark for ions become hydrated.

d. Draw a diagram to show the different arrangement of water molecules around dissolved potassium and chloride ions.

Solution



2 marks

Mark allocation

- 1 mark for showing the potassium ion surrounded by water molecules.
- 1 mark for showing the chloride ion surrounded by water molecules.

Explanatory notes

The water molecules orientate differently around anions and cations. Around cations the oxygen is on the inside, whereas around anions the hydrogens are on the inside.

Total 1 + 1 + 2 + 2 = 6 marks

Question 3

a. Give a definition and example of a strong base.

Solution

A strong base is a proton acceptor that completely dissociates in water and readily accepts protons. Examples include NaOH and Na_2O.

3 marks

Mark allocation

- 1 mark for a base is a proton acceptor.
- 1 mark for a strong base completely dissociates or readily accepts protons.
- 1 mark for supplying a correct example.

Explanatory notes

- A strong base or strong acid should never be defined in terms of their pH because pH is contributed to by both strength and concentration.
- Both O^{2-} and OH^- are strong bases, and there is a wide range of cations they can bond with to form a strong base.

b. Give a definition and an example of a weak acid.

Solution

A weak acid is a proton donor that does not ionise completely in water **or** a substance that does not readily donate protons. Examples include NH_4^+, CH_3COOH and HSO_4^-.

2 marks

Mark allocation

- 1 mark for acids are proton donors that do not readily donate protons.
- 1 mark for supplying a correct example.

c. Calculate the pH of a 500 mL solution in which 0.846 g of gaseous hydrogen chloride is dissolved.

Solution

$$n(\text{HCl}) = \frac{m}{M}$$
$$= \frac{0.846}{1.0 + 35.5}$$
$$= \frac{0.846}{36.5}$$
$$= 0.0232 \text{ mol}$$

$$c(\text{HCl}) = \frac{n}{V}$$
$$= \frac{0.0232}{0.500}$$
$$= 0.0464 \text{ M}$$

HCl is a strong, monoprotic acid, so $[H_3O^+] = [HCl] = 0.0464$ M.

$$\text{pH} = -\log_{10}[H_3O^+]$$
$$= -\log_{10}(0.0463)$$
$$= 1.33$$

3 marks

Mark allocation

- 1 mark for correct calculation of n(HCl).
- 1 mark for correct calculation of c(HCl).
- 1 mark for correct use of $\text{pH} = -\log_{10}[H_3O^+]$.

Explanatory notes

Consequential marks should be awarded if an error is made affecting the numerical answers but the subsequent working is correct.

d. A 7.43 g sample of copper sulfide is added to an excess amount of 1.50 M hydrochloric acid. The reaction that occurs is represented by the equation

$$CuS(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2S(g)$$

i. Calculate the volume, in L, of HCl required to react with all of the CuS.

Solution

$$n(\text{CuS}) = \frac{m}{M}$$
$$= \frac{7.43}{(63.6 + 32.1)}$$
$$= 0.0776 \text{ mol}$$

According to the equation:

n(HCl) : n(CuS)

2 : 1

So, $n(\text{HCl}) = \frac{2}{1} \times n(\text{CuS})$

$$= \frac{2}{1} \times 0.0776$$
$$= 0.155 \text{ mol}$$

$$V(\text{HCl}) = \frac{n}{c}$$
$$= \frac{0.155}{1.50}$$
$$= 0.104 \text{ L}$$

3 marks

Mark allocation

- 1 mark for correct calculation of n(CuS).
- 1 mark for correct calculation of n(HCl).
- 1 mark for correct calculation of V(HCl).

Explanatory notes

- Consequential marks should be awarded.

ii. If a student carried out this experiment on a balance, what would be the total loss of mass observed by the student at the end of the experiment compared with the beginning?

Solution

Mass is conserved in a chemical reaction, so any mass loss observed on a balance will be due only to a gaseous product escaping, in this case H_2S.

$n(H_2S) : n(CuS)$
1 : 1
So, $n(H_2S) = n(CuS)$
$= 0.0776$ mol
$m(H_2S) = n \times M$
$= 0.0766 \times (2 \times 1.0 + 32.1)$
$= 2.65$ g
There will be a mass loss of 2.65 g.

2 marks

Mark allocation

- 1 mark for recognition that any mass loss is due only to any produced gas escaping.
- 1 mark for correct calculation of 2.65 g.

Total 3 + 2 + 3 + 5 = 13 marks

Question 4

Write balanced chemical equations to represent each of the following chemical reactions. Remember to include states in your equations.

a. A small volume of liquid ethanol, C_2H_5OH, is dissolved in water.

Solution

$$C_2H_5OH(l) \xrightarrow{H_2O(l)} C_2H_5OH(aq)$$

1 mark

Explanatory notes

- Correct states must be shown to obtain the mark.
- Ethanol is a polar covalent molecule that can form hydrogen bonds. It does not react directly with water molecules. Rather, the hydrogen bonds between different ethanol molecules break and hydrogen bonds between ethanol and water molecules form.

b. A small sample of gaseous hydrogen chloride is dissolved in water.

Solution

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

2 marks

Mark allocation

- 1 mark for correct formulas and correctly balanced equation.
- 1 mark for correct states.

Explanatory notes

Hydrogen chloride is a polar covalent molecule that ionises. The covalent bond between H and Cl atoms in the hydrogen chloride molecule breaks and a new covalent bond forms between the hydrogen atom from the HCl molecule and the O atom on the H_2O molecule.

Tip

- *HCl can't dissolve by forming hydrogen bonds because a molecule can form intermolecular hydrogen bonds only if it has a H atom attached to a N, O or F atom.*

c. A precipitate forms when aqueous silver nitrate is added to aqueous sodium chloride.

Solution

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

2 marks

Mark allocation

- 1 mark for correct formulas and correctly balanced equation.
- 1 mark for correct states.

Explanatory notes

A precipitate is an insoluble substance that forms when two solutions are mixed.

Tips

- *It is useful to remember that:*
  - *All compounds containing a nitrate ion are soluble.*
  - *All compounds of Group 1 elements are soluble.*

d. Aqueous hydrochloric acid and sodium carbonate are mixed and bubbles are observed.

Solution

$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

2 marks

Mark allocation

- 1 mark for correct formulas.
- 1 mark for correctly balanced equation.

Explanatory notes

Acids undergo common reactions with many substances. When an acid reacts with a metal carbonate, such as sodium carbonate, the products will be a salt, water and carbon dioxide gas. The carbon dioxide gas is responsible for the bubbles that are observed.

e. Silver ions are reduced by nickel metal.

Solution

$2Ag^+(aq) + Ni(s) \rightarrow Ni^{2+}(aq) + 2Ag(s)$

2 marks

Mark allocation

- 1 mark for correct species.
- 1 mark for a correctly balanced equation.

Explanatory notes

- A consequential mark may be awarded if incorrect valencies are allocated to silver ions and nickel ions but the equation is balanced overall.
- The reduction of silver ions involves the gain of one electron: $Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$. The oxidation of nickel metal involves the loss of two electrons: $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^{-}$. In the overall equation the number of electrons must be balanced, so the reduction of silver occurs twice for each oxidation of nickel.

f. Respiration by plants returns carbon dioxide to the atmosphere.

Solution

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6H_2O(l) + 6CO_2(g)$

1 mark

Explanatory notes

Respiration is an important reaction in the carbon cycle. It is carried out by both plants and animals to release energy from food.

Tip

- *Respiration is the reverse equation of photosynthesis but is catalysed by different enzymes.*

Total 1 + 2 + 2 + 2 + 2 + 1 = 10 marks

Question 5

During your studies of Unit 2 Chemistry, you will have examined the laboratory and industrial preparation of one gas of significance to the quality of the atmosphere. Write the name of the gas you studied here.

a. List two properties of this gas.

Solution

Any one of the following:

Carbon dioxide – two of: colourless, odourless, does not support combustion, denser than air, sublimes at –78°C, slightly soluble in water, slightly acidic when dissolved in water, turns limewater milky.

Oxygen – two of: colourless, odourless, slightly soluble in water, supports combustion, generally reactive.

2 marks

Mark allocation

- 1 mark for each property for a total of 2 marks.

b. Describe the laboratory preparation of this gas. Include an appropriate equation in your answer.

Solution

Any one of the following:

Carbon dioxide – A reaction between hydrochloric acid with calcium carbonate chips.
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

Oxygen – Decomposition of hydrogen peroxide solution using manganese dioxide as a catalyst.
$2H_2O_2(aq) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$

2 marks

Mark allocation

- 1 mark for description of preparation.
- 1 mark for an appropriate equation.

c. A reduction in the quality of the atmosphere can have significant consequences for the occupants of Earth. The enhanced greenhouse effect is one such problem.

i. Describe the enhanced greenhouse effect.

Solution

Levels of greenhouse gases are increasing too quickly and too much heat from the Sun is being trapped at the Earth's surface, which could cause global warming.

ii. List two human activities that have contributed to the enhanced greenhouse effect.

Solution

Two of: combustion of fossil fuels (i.e. coal, oil and natural gas); deforestation; agricultural activities, such as rice farming and increasing livestock numbers; increased landfills.

1 + 2 = 3 marks

Mark allocation

- 1 mark for each activity to a total of 2 marks.

d. Acid rain is another serious problem resulting from a decrease in the quality of the atmosphere. Use an equation to describe the production of acid rain from a gas in the atmosphere and outline one of the effects of acid rain on plants or animals.

Solution

Acid rain forms when water vapour combines with different gases in the atmosphere.
Equation could be any one of: $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

$2NO_2(g) + H_2O(g) \rightarrow HNO_2(aq) + HNO_3(aq)$

Effect could be any one of:

- damages surfaces of plants so they are unable to carry out photosynthesis effectively
- decreases pH of lakes, which may lead to death of organisms
- acidifies soils and damages plant root systems.

2 marks

Mark allocation

- 1 mark for correct equation.
- 1 mark for describing effect of acid rain on plants or animals.

Total 2 + 2 + 3 + 2 = 9 marks

Question 6

Use kinetic molecular theory to explain the following observations.

a. A sample of methane that is released on one side of a large room is soon smelled by a student standing on the other side of the room.

Solution

Gas particles move rapidly in random, straight-line motion.

1 mark

b. An aerosol can that is heated too strongly may explode.

Solution

The average kinetic energy (speed) of gas particles increases as the temperature of the gas increases. If the gas is in a fixed volume can, increasing the temperature will cause an increase in the pressure as the particles collide with the walls of the can more frequently, and may cause it to explode.

2 marks

Mark allocation

- 1 mark for average kinetic energy increases as temperature increases.
- 1 mark for pressure in the can increases.

c. The gas-filled tyres of modern motor vehicles provide a much smoother ride than the solid wagon wheels on the early horse and carts.

Solution

Gases mostly consist of empty space and so can be compressed. When a car travels over small bumps in the road, the tyres are compressed slightly, so the passengers do not feel the bumps. In a cart with solid wheels, the whole cart would move up and down with each bump, as solids cannot be compressed.

2 marks

Mark allocation

- 1 mark for gases are mostly empty space.
- 1 mark for the tyres can be compressed.

Total 1 + 2 + 2 = 5 marks

Question 7

a. The Hazelwood power station in the Latrobe Valley uses about 36 000 tonnes of coal each day (1 tonne = 10^6 g). The coal used in the power station contains about 25.0% carbon. Calculate the volume of carbon dioxide, in L, released each day by the power station at STP that is due to the burning of carbon in coal.

Solution

Mass of carbon in the coal = 25% of 36 000 × 10^6 g

$$= \frac{25}{100} \times 36\,000 \times 10^6$$
$$= 9.00 \times 10^9 \text{ g}$$

$$n(\text{C}) = \frac{m}{M}$$
$$= \frac{9.00 \times 10^9}{12.0}$$
$$= 7.50 \times 10^8 \text{ mol}$$

When carbon combusts, the reaction is: $C(s) + O_2(g) \rightarrow CO_2(g)$

So, $n(CO_2) = n(C)$
$= 7.50 \times 10^8$ mol

$V(CO_2) = n \times V_M$
$= 7.50 \times 10^8 \times 22.4$
$= 1.68 \times 10^{10}$ L

4 marks

Mark allocation

- 1 mark for correct calculation of the mass of carbon in the coal.
- 1 mark for correct calculation of the amount, in mol, of carbon.
- 1 mark for correct calculation of the amount, in mol, of carbon dioxide.
- 1 mark for correct calculation of the volume, in L, of carbon.

Explanatory notes

Consequential marks should be awarded if calculations are carried out correctly using an incorrect number resulting from an earlier error.

At STP, the volume of one mole of any gas will occupy 22.4 L.

b. In 1766, Cavendish prepared hydrogen gas by passing steam through a red-hot gun barrel. The reaction can be represented by the equation

$$4H_2O(g) + 3Fe(s) \rightarrow Fe_3O_4(s) + 4H_2(g)$$

Calculate the volume of hydrogen at a pressure of 780 mmHg and a temperature of 27°C that can be prepared from the reaction of 20.0 g of water.

Solution

$$n(H_2O) = \frac{m}{M}$$
$$= \frac{20.0}{(2\times1.0+16.0)}$$
$$= 1.11 \text{ mol}$$

From the mole ratio in the equation:

$$n(H_2O) : n(H_2)$$
$$4 : 4$$

$$\text{So, } n(H_2) = \frac{4}{4}\times n(H_2O)$$
$$= 1.11 \text{ mol}$$

$$V(H_2) = \frac{nRT}{P}$$
$$= \frac{1.11\times8.31\times300}{104}$$
$$= 26.6 \text{ L}$$

4 marks

Mark allocation

- 1 mark for correct calculation of the amount, in mol, of hydrogen gas.
- 1 mark for correct conversion of the temperature to 300 K.
- 1 mark for correct conversion of the pressure to 104 kPa.
- 1 mark for correct use of $PV = nRT$.

Explanatory notes

The general gas equation requires pressure to be in kPa and temperature to be in K. Remember that T (K) = t (°C) + 273. The pressure relationship to use is that 760 mmHg = 101.3 kPa. Hence, 780 mmHg = $\frac{780}{760}\times101.3$ KPa.

Total 4 + 4 = 8 marks

END OF SOLUTIONS BOOK