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CHEMISTRY

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Sample HSC Examination Paper with 2018 HSC Questions

Chemistry

- Reading time — 5 minutes
- Working time — 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this book (pp. 321–324)
- For questions in Section II, show all relevant working in questions involving calculations

Section I – 20 marks

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks

- Attempt Questions 21–34
- Allow about 2 hours and 25 minutes for this section

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Section 1

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

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1 Hypochlorous acid (HOCl) can produce small amounts of chlorine, $Cl_2(aq)$, in water according to the equation:

$$HOCl(aq) + H^+(aq) + Cl^-(aq) \rightleftarrows Cl_2(aq) + H_2O(l).$$

Which of the following changes would raise the concentration of Cl_2 in the solution?

A. Adding a KOH solution

B. Adding a HNO_3 solution

C. Removing HOCl

D. Removing the chloride ion by precipitation with a silver nitrate solution

(Sample question)

2 Identify a suitable laboratory test or instrumental procedure that will distinguish between an aqueous solution of ethanol and a solution of ammonium chloride.

A. Flame test

B. Colourimetry

C. Electrical conductivity

D. Titration with a weak acid

(Sample question)

3 An esterification reaction is to be performed.

Which of the following substances, when added, would increase the yield of the product?

A. Water

B. Boiling chips

C. More alkanol

D. Dilute sulfuric acid

(2018 HSC)

4 Which of the following greatly enhanced scientific understanding of the effects of trace elements?

A. Improved filtration techniques

B. The development of atomic absorption spectroscopy

C. The creation of new elements in particle accelerators

D. The work of Le Chatelier in describing chemical equilibrium

(2018 HSC)

5 Cellulose extracted from biomass is able to be used as a raw material in the manufacture of polymers because it

A. is a condensation polymer.

B. is a strong flexible molecule.

C. produces carbon dioxide when burnt.

D. contains a basic carbon-chain structure.

(2018 HSC)

6 Sodium hydrogen carbonate is often used to clean up large spills of acids and alkalis.

Why is it a suitable chemical for this application?

A. It is diprotic and is readily neutralised.

B. It is amphiprotic, stable and easily handled.

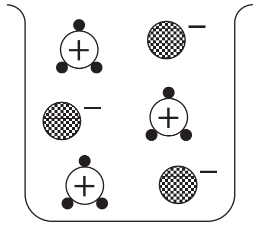
C. It is diprotic and easily cleaned up when neutralised.

D. It is amphiprotic and only small quantities are required.

(2018 HSC)

7 Which diagram represents ionisation of a weak acid?

A.



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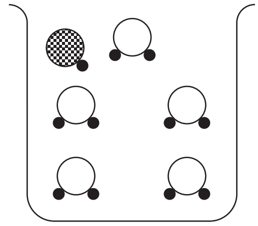

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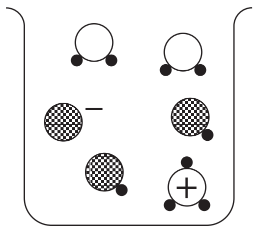

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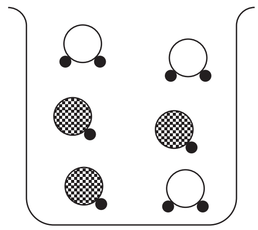

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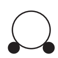


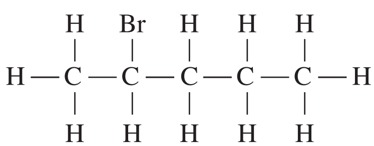
Water molecule

Molecule of weak acid

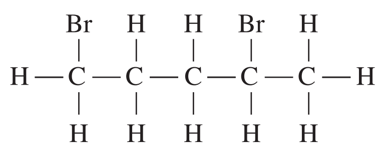
(2018 HSC)

8 Identify the structure of the product formed when pent-2-ene reacts with bromine.

A.



B.



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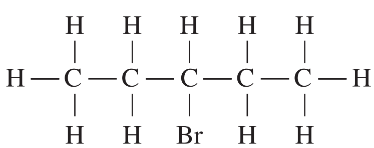

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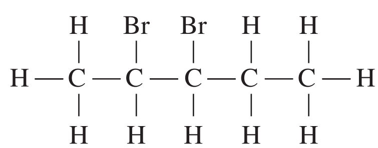


(Sample question)

9 Which of the following would NOT have been classified as an acid by Antoine Lavoisier in 1780?

A. Acetic acid

B. Citric acid

C. Sulfuric acid

D. Hydrochloric acid

(2018 HSC)

10 Which row of the table correctly matches the reaction type with the reactant(s), catalyst and product(s)?

	Reaction type	*Reactant(s)*	*Catalyst*	*Product(s)*
A.	Hydration	$C_2H_4 + H_2O$	Dilute acid	C_2H_6
B.	Hydration	C_2H_4	Concentrated acid	C_2H_5OH
C.	Dehydration	C_2H_5OH	Dilute acid	C_2H_4
D.	Dehydration	C_2H_5OH	Concentrated acid	$C_2H_4 + H_2O$

(2018 HSC)

11 Which row of the table correctly matches the polymer with its structural feature and property?

	Polymer	*Structural feature*	*Property*
A.	Polyvinyl chloride	Chlorine side group	Rigid
B.	Low density polyethylene	Tightly packed molecules	Opaque
C.	High density polyethylene	Branched chains	Transparent
D.	Polystyrene	Large side chains	Flexible

(2018 HSC)

12 A small piece of sodium metal was added to a colourless liquid in a test tube. An effervescence (fizzing) of a colourless gas was observed. Which of the following organic compounds could have been in the test tube?

A. Methanol

B. Oct-1-ene

C. Heptane

D. Propyl acetate

(Sample question)

13 Pentanol, propyl acetate, pentanoic acid and ethyl propanoate all contain five carbon atoms. These four compounds are mixed in a flask and then separated by fractional distillation.

Which compound would be most likely to remain in the flask?

A. Pentanol

B. Propyl acetate

C. Pentanoic acid

D. Ethyl propanoate

(2018 HSC)

14 How many isomers are there of C_3H_6ClF?

A. 3

B. 4

C. 5

D. 6

(2018 HSC)

15 A solution containing potassium dihydrogen phosphate and potassium hydrogen phosphate is a common laboratory buffer with a pH close to 7.

Which row of the table correctly identifies the chemistry of this buffer?

	Buffer equation	*Equilibrium shift*	
		Acid is added to the solution	*Alkali is added to the solution*
A.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Right	Left
B.	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	Left	Right
C.	$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Right	Left
D.	$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$	Left	Right

(2018 HSC)

16 An investigation was carried out to determine the calcium ion concentration of a 2.0 L sample of tap water. Excess Na_2CO_3 was added to the sample. The precipitate was filtered, dried and weighed. The mass of the dried precipitate was 400 mg.

What was the concentration of calcium ions in the sample of tap water?

A. 80 mg L^{-1}

B. 160 mg L^{-1}

C. 200 mg L^{-1}

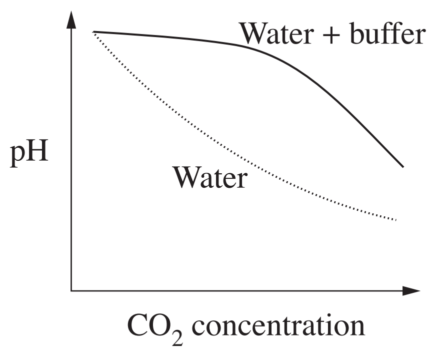
D. 400 mg L^{-1}

(2018 HSC)

17 Increasing amounts of carbon dioxide were dissolved in two beakers, one containing water and one a mixture of water and a buffer. The pH in each beaker was measured and the results graphed.

Which graph best represents the results?

A.



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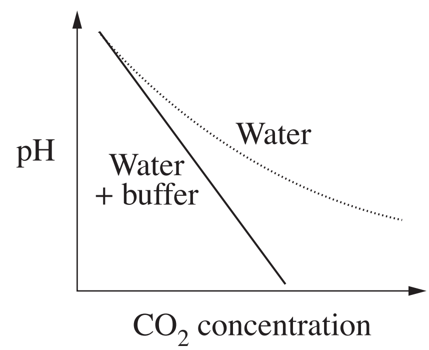

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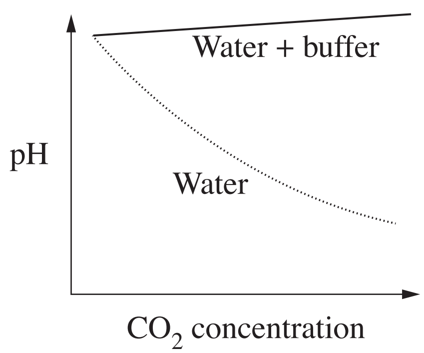

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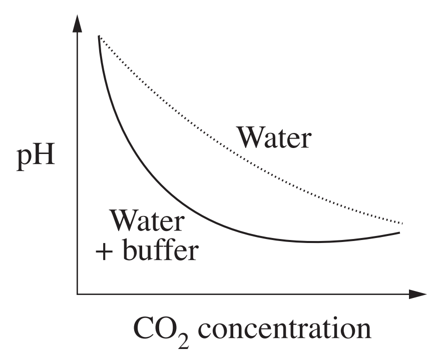


(2018 HSC)

18 The pH of a 0.080 mol L^{-1} solution of acetic acid is 2.9.

What percentage of the acetic acid has dissociated into ions?

A. 1.1%

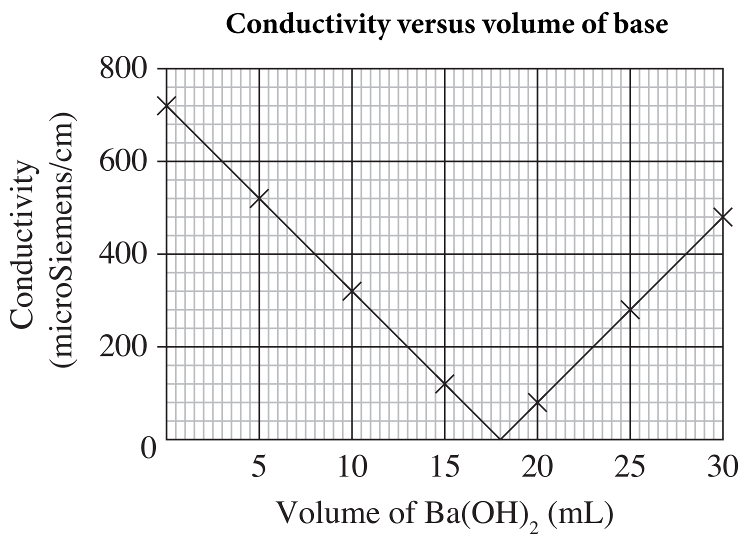
B. 1.3%

C. 1.6%

D. 2.8%

(2018 HSC)

19 25.00 mL of 0.0100 mol/L sulfuric acid was pipetted into a beaker and conductivity electrodes were inserted. A burette was filled with a dilute barium hydroxide solution. A conductivity titration was performed. The results are shown in the graph.



Calculate the concentration of the barium hydroxide solution.

A. 0.046 mol/L

B. 0.028 mol/L

C. 0.023 mol/L

D. 0.014 mol/L

(Sample question)

20 The Winkler method is used to determine the amount of dissolved oxygen in a water sample. The procedure involves the following sequence of reactions.

Step 1. $2Mn^{2+}(aq) + O_2(g) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$

Step 2. $MnO(OH)_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow I_2(aq) + Mn^{2+}(aq) + 3H_2O(aq)$

Step 3. $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

When a 5.00 L sample of water was analysed using the Winkler method, a total of 4.00×10^{-3} mol of thiosulfate ($S_2O_3^{2-}$) was required in Step 3.

What concentration of oxygen was present in the original sample?

A. 3.20 mg L^{-1}

B. 6.40 mg L^{-1}

C. 12.8 mg L^{-1}

D. 32.0 mg L^{-1}

(2018 HSC)

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Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.

Please turn over

Question 21 (3 marks) **Marks**

Ethylene can be readily transformed into many useful products.

(a) What is the name of the industrial process by which ethylene is obtained from long chain alkanes? **1**

....

(b) Ethylene can be converted into vinyl chloride. **2**

Draw structural formulae for vinyl chloride and its polymer, polyvinyl chloride.

Vinyl chloride

Polyvinyl chloride

(2018 HSC)

Question 22 (4 marks) **Marks**

A bottle of solution is missing its label. It is either $Pb(NO_3)_2$, $Ba(NO_3)_2$ or $Fe(NO_3)_2$. **4**

Using only HCl, NaOH and H_2SO_4 solutions, outline a sequence of steps that could be followed to confirm the identity of the solution in the bottle. Include observed results and ionic equations in your answer.

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(2018 HSC)

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Question 23 (6 marks) **Marks**

A student makes an ester in the school laboratory using methanol and butanoic acid.

(a) Using structural formulae, write an equation for this reaction. **2**

(b) Explain the conditions needed to efficiently and safely carry out this reaction in the school laboratory. **4**

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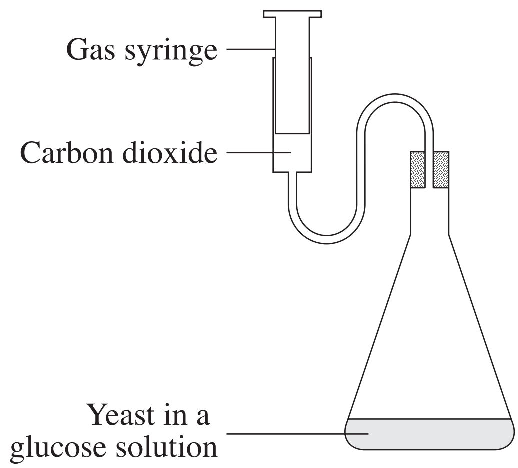
(2018 HSC)

Question 24 (4 marks) **Marks**

The following apparatus was set up to test the reaction rate of fermentation of glucose at different temperatures.



(a) Write a balanced equation for the fermentation of glucose. **1**

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(b) After 24 hours, 5.5 mL of gas was collected at 25 °C and 100 kPa. **3**

Calculate the mass of glucose that would have been reacted.

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(2018 HSC)

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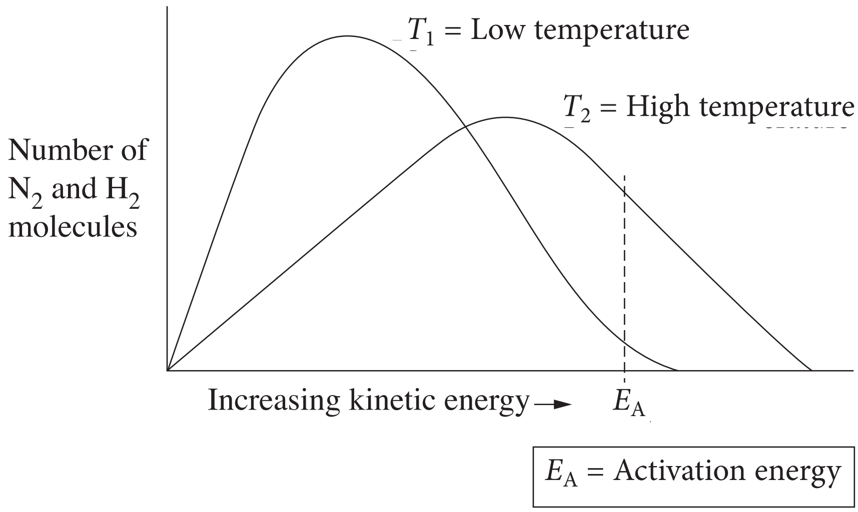
Question 25 (4 marks) **Marks**

The graph shows the number of molecules of N_2 and H_2 that possess a certain kinetic energy at two different temperatures. **4**



With reference to the graph, explain why changing the temperature and adding a catalyst would change the rate of production of ammonia.

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(2018 HSC)

Question 26 (8 marks) **Marks**

Acetic acid is a weak organic monoprotic acid. The K_a of acetic acid is 1.74×10^{-5}. The degree of dissociation of a 0.10 mol/L acetic acid solution is 1.3%.

(a) Write the equation for the dissociation equilibrium of acetic acid in water. **1**

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(b) Calculate the pH of a 0.10 mol/L acetic acid solution. **4**

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(c) Potassium acetate is a soluble salt. How will the pH of the 0.10 mol/L solution of acetic acid change as small amounts of potassium acetate are dissolved in the solution? **1**

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(d) Calculate the pK_a of acetic acid. **1**

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(e) Butanoic acid has a pK_a of 4.82. Identify whether acetic acid or butanoic acid is the weaker acid. **1**

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(Sample question)

Question 27 (4 marks) **Marks**

The Aboriginal people in northern Australia have long known of the health benefits of the Kakadu plum. This native plum was known to assist in reducing the symptoms of colds, as well as treating skin sores and scurvy. Chemists later discovered that the plum had a very high ascorbic acid content. **4**

100 g of plum flesh was analysed by an analytical chemist. The ascorbic acid was extracted from the flesh into 100 mL of water. Below pH 11, ascorbic acid behaves as a monoprotic acid. Its molecular formula is $HC_6H_7O_6$.

The ascorbic acid solution was placed in a conical flask and titrated. The acid solution was neutralised by 23.40 mL of a 1.00 mol/L sodium hydroxide solution. Calculate the percentage by weight of ascorbic acid in the plum flesh.

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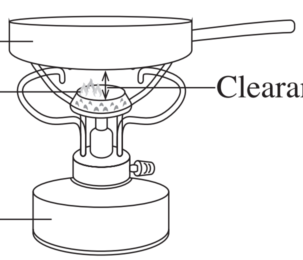
(Sample question)

Question 28 (8 marks)

A camp stove using butane as a fuel was used to heat a pot of water inside a small tent. Poisonous carbon monoxide (CO) gas can be released from these stoves.



An investigation was carried out to determine the carbon monoxide concentration in the tent when the clearance height of the pot above the flame was altered. The results are shown in the table.

Clearance height (mm)	35	40	45	50
CO concentration (ppm)	120	87	50	18

Question 28 continues

Question 28 (continued) **Marks**

(a) Construct a graph of the data on the grid. **3**

(b) Air containing a CO concentration above 30 ppm is considered unsafe to breathe. **1**

What is the minimum clearance height at which the pot should be placed?

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Question 28 continues

Question 28 (continued) **Marks**

(c) Increasing the clearance height decreases the efficiency of the stove according to the following table. **4**

Clearance height (mm)	35	40	45	50
Efficiency (%)	90	70	50	30

A bushwalker only has 15.0 g of butane with which to heat 1.0 L of water with a starting temperature of 20 °C.

Calculate the highest temperature of the water that could safely be achieved in the tent. (Molar heat of combustion of butane: $\Delta H_c = 2877\ \text{kJ mol}^{-1}$)

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(2018 HSC)

End of Question 28

Question 29 (7 marks) **Marks**

The concentration of hydrochloric acid in a solution was determined by an acid-base titration using a standard solution of sodium carbonate.

(a) Explain why sodium carbonate is a suitable compound for preparation of a standard solution. **2**

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(b) A 25.00 mL sample of 0.1050 mol L^{-1} sodium carbonate solution was added to a conical flask and three drops of methyl orange indicator added. The mixture was titrated with the hydrochloric acid and the following readings were recorded. **3**

Initial burette reading (mL)	*Final burette reading* (mL)	*Titre* (mL)
0.00	22.00	22.00
22.00	43.65	21.65
0.00	21.70	21.70
21.70	43.30	21.60

Using the data from the table, calculate the concentration of the hydrochloric acid.

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Question 29 continues

Question 29 (continued) **Marks**

(c) Explain the effect on the calculated concentration of hydrochloric acid if phenolphthalein is used as the indicator instead of methyl orange. **2**

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(2018 HSC)

End of Question 29

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Question 30 (7 marks) **Marks**

Over the last 50 years, scientists have recorded increases in the following: **7**

- the amount of fossil fuels burnt
- atmospheric carbon dioxide levels
- average global air temperature and ocean temperature
- the volume of carbon dioxide dissolved in the oceans.

Analyse the factors that affect the equilibrium between carbon dioxide in the air and carbon dioxide in the oceans. In your answer, make reference to the scientists'observations and include relevant equations.

Question 30 continues

Question 30 (continued)

(2018 HSC)

End of Question 30

Question 31 (7 marks) **Marks**

Lead (II) bromide has a solubility of 0.973 g/100 g water at 20 °C. Determine the solubility product constant for lead (II) bromide and determine whether a precipitate will form if 100 mL (100 g) of 0.0010 mol/L solutions of KBr and $Pb(NO_3)_2$ are mixed. (1 g water = 1 mL) **7**

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(Sample question)

Question 32 (6 marks)

Compare the structure, properties and uses of low density polyethylene (LDPE) and polytetrafluoroethylene (PTFE). **6**

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(Sample question)

Question 33 (6 marks) **Marks**

Solutions of zinc sulfate contain tetraaquazinc (II) ions and sulfate ions. These solutions are acidic. Solutions of potassium formate, however, are basic. Use the Brønsted–Lowry theory to explain these observations and describe a qualitative laboratory procedure to demonstrate these conclusions. **6**

(Sample question)

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Question 34 (6 marks) **Marks**

A liquid organic molecule (X) has the molecular formula $C_5H_{12}O$. The liquid was mixed with acidified potassium dichromate and the mixture turns from orange to green on heating. The liquid product (Y) of this reaction was isolated from the reaction mixture and the C-13 NMR spectrum of X and Y were recorded. These spectra showed the following information: **6**

X: 3 peaks
Y: 3 peaks

Liquids X and Y were tested with sodium carbonate solution. No effervescence occurred with either compound.

Use this data to identify X and Y. Draw structures for each compound and name them systematically.

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(Sample question)

Sample HSC Examination Paper with 2018 HSC Questions

Sample Answers

Section I

1 B HNO_3 will increase the hydrogen ion concentration and shift the equilibrium to the right to increase the chlorine concentration.

2 C

3 C

4 B

5 D

6 B

7 C

8 D

9 D

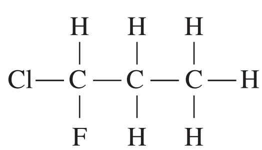
10 D

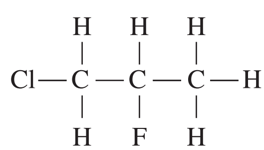
11 A

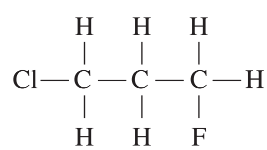
12 A

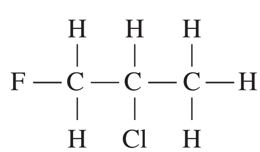
13 C Pentanoic acid has the strongest intermolecular forces between its molecules. It has the greatest polarity as well as some hydrogen bonding.

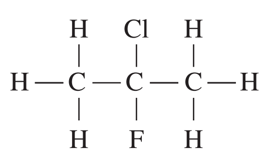
14 C


1-chloro-1-fluoropropane


1-chloro-2-fluoropropane


1-chloro-3-fluoropropane


2-chloro-1-fluoropropane


2-chloro-2-fluoropropane

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15 D

16 A $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

$m(CaCO_3) = 400 \text{ mg} = 0.400 \text{ g}$

$M(CaCO_3) = 40.08 + 12.01 + (16.00 \times 3) = 100.09 \text{ g/mol}$

$$n(CaCO_3) = \frac{m}{M} = \frac{0.400}{100.09} = 3.9964 \times 10^{-3} \text{ mol}$$

$n(Ca^{2+}) = n(CaCO_3) = 3.9964 \times 10^{-3} \text{ mol}$

$m(Ca^{2+}) = nM = (3.9964 \times 10^{-3})(40.08) = 0.160 \text{ g} = 160 \text{ mg}$

$$c(Ca^{2+}) = \frac{m}{V} = \frac{160}{2.0} = 80 \text{ mg/L}$$

17 A

18 C $[H^+] = 10^{-pH} = 10^{-2.9} = 1.259 \times 10^{-3} \text{ mol/L}$

$$\% \text{ dissociation} = \frac{[H^+]}{[CH_3COOH]} \times \frac{100}{1} = \left(\frac{1.259 \times 10^{-3}}{0.080}\right) \times \frac{100}{1} = 1.6\%$$

19 D $H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$

At the equivalence point the conductivity is zero as water is a non-conductor and the barium sulfate is insoluble.

$V(Ba(OH)_2)$ at equivalence point = 18 mL = 0.018 L

$n(H_2SO_4) = cV = (0.0100)(0.025\,00) = 0.000\,2500 \text{ mol} = n(Ba(OH)_2)$

$$c(Ba(OH)_2) = \frac{n}{V} = \frac{0.000\,2500}{0.018} = 0.014 \text{ mol/L}$$

20 B Net stoichiometry: $O_2 : S_2O_3^{2-} = 1 : 4$ (step 1 + 2 × step 2 + 2 × step 3)

$n(S_2O_3^{2-}) = 4.00 \times 10^{-3} \text{ mol}$

$$n(O_2) = \frac{1}{4} \times 4.00 \times 10^{-3} = 1.00 \times 10^{-3} \text{ mol}$$

$$c(O_2) = \frac{1.00 \times 10^{-3}}{5.00} = 2.00 \times 10^{-4} \text{ mol/L}$$

$m(O_2) = nM = 2.00 \times 10^{-4} \times (2 \times 16.00) = 6.40 \times 10^{-3} \text{ g} = 6.40 \text{ mg}$

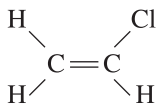
$c(O_2) = 6.40 \text{ mg/L}$

Section II

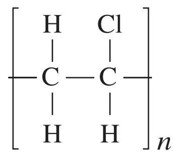
Question 21 (Total 3 marks)

(a) Thermal cracking *(1 mark)*

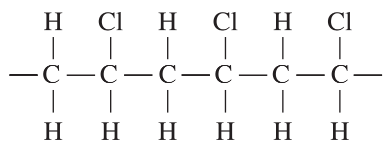
(b)



Vinyl chloride



Polyvinylchloride



3 monomer section of PVC polymer

(2 marks)

Question 22 (Total 4 marks)

1 To a 20 mL sample of the unknown solution add hydrochloric acid. If a white precipitate forms then the unknown is $Pb(NO_3)_2$.

$$Pb^{2+}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_2(s)$$

If no precipitate forms then lead (II) nitrate is excluded.

2 If no precipitate forms in Step 1, add sulfuric acid. If a white precipitate forms then $Ba(NO_3)_2$ is present.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

If no precipitate forms then barium nitrate is excluded.

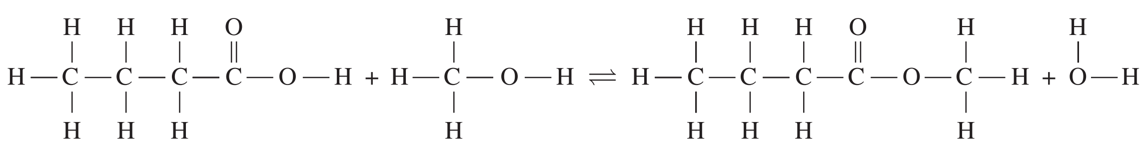
3 If no precipitate forms in Step 2, add sodium hydroxide. A green precipitate indicates iron (II) nitrate is present.

$$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$$

Balanced ionic equations must be shown. *(4 marks)*

Question 23 (Total 6 marks)

(a)



Butanoic acid Methanol Methyl butanoate Water

(2 marks)

(b) *Reaction efficiency and safety issues*

Efficiency:

Increased rate: moderate heating (using an electric heating mantle); adding a catalyst such as concentrated sulfuric acid

Increased ester yield: an excess of one reactant (e.g. alkanoic acid) will cause the equilibrium to shift to the right to make more ester.

Safety:

To avoid a loss of the volatile components the reaction is performed using a water-cooled reflux condenser. The condenser is open to the atmosphere and so dangerous vapour pressure build-up is avoided. Small boiling chips are used to prevent dangerous vibrations during reflux.

The organic chemicals are flammable and therefore the reaction flask should be heated with an electric mantle rather than a Bunsen burner. A hot water bath can be used in some cases where the boiling points of the reactants is less than 100 °C. *(4 marks)*

Question 24 (Total 4 marks)

(a) $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$ *(1 mark)*

(b) $n(CO_2) = \dfrac{V}{V_M} = \dfrac{5.5\times10^{-3}}{24.79} = 2.22 \times 10^{-4}$ mol

$n(\text{glucose}) = \dfrac{n(CO_2)}{2} = 1.11 \times 10^{-4}$ mol

$$\begin{aligned} m(\text{glucose}) &= nM \\ &= (1.11 \times 10^{-4})((12.01 \times 6) + (1.008 \times 12) + (16.00 \times 6)) \\ &= (1.11 \times 10^{-4})(180.156) \\ &= 2.0 \times 10^{-2}\ \text{g} \end{aligned}$$

(3 marks)

Question 25 (Total 4 marks)

Each graph shows that in a system of gas molecules at a fixed temperature, there is a distribution of molecular velocities. Some molecules are moving more rapidly than others at a fixed temperature. As the temperature of the system increases from T_1 to T_2 there is an increasing proportion of molecules with higher molecular velocities.

If the system consists of a mixture of reacting gases such as nitrogen and hydrogen their kinetic energies increase if the temperature is increased. If the kinetic energy of the molecules exceeds the activation energy on collision then a reaction will occur. At the higher temperature (T_2) the number of molecules having an energy greater than E_A has increased compared with the lower temperature (T_1).

The production of ammonia by the reaction of the nitrogen and hydrogen is an exothermic equilibrium.

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

The activation energy for the reverse reaction (E_A(r)) is greater than the activation energy for the forward reaction (E_A(f)). As the temperature increases from T_1 to T_2 the rates of the forward and reverse reactions both increase but the reverse rate increases to a greater extent due to a greater proportion of product molecules having kinetic energies greater than the reverse activation energy. The equilibrium shifts to the left as predicted by Le Chatelier's Principle. When equilibrium is attained at T_2 there will be a decrease in the equilibrium yield of ammonia as a result.

The presence of an iron catalyst lowers the activation energy and so the rates of the forward reaction and the reverse reaction increase equally and equilibrium is achieved more quickly. There is, however, no change in the equilibrium yield of ammonia at the fixed temperature. *(4 marks)*

Question 26 (Total 8 marks)

(a) $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ *(1 mark)*

(b) As acetic acid dissociates, equal concentrations of hydrogen ions and acetate ions result. Let this concentration = x mol/L.

The concentration of acetic acid decreases. The decrease in concentration

$= \left(\frac{1.3}{100}\right) \times 0.10$ mol/L

$= 1.3 \times 10^{-3}$ mol/L CH_3COOH

Equilibrium concentration of $CH_3COOH = 0.10 - 1.3 \times 10^{-3} = 0.0987$ mol/L

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{(x)(x)}{(0.0987)} = 1.74 \times 10^{-5}$$

Solve for x.

$x = [H^+] = 1.31 \times 10^{-3}$ mol/L

$pH = -\log_{10}(H^+) = -\log_{10}(1.31 \times 10^{-3}) = 2.88$ (2 sig. figs) *(4 marks)*

(c) An increase in the acetate concentration will drive the equilibrium to the left (according to Le Chatelier's Principle) and reduce the hydrogen ion concentration. Therefore the pH will increase. *(1 mark)*

(d) $pK_a = -\log_{10}K_a = -\log_{10}(1.74 \times 10^{-5}) = 4.76$ *(1 mark)*

(e) Butanoic acid is weaker than acetic acid as its pK_a is greater. *(1 mark)*

Question 27 (Total 4 marks)

$HC_6H_7O_6(aq) + NaOH(aq) \rightarrow NaC_6H_7O_6(aq) + H_2O(l)$

1 : 1 stoichiometry

$n(\text{NaOH}) = c.V = (1.00)(0.02340) = 0.0234$ mol

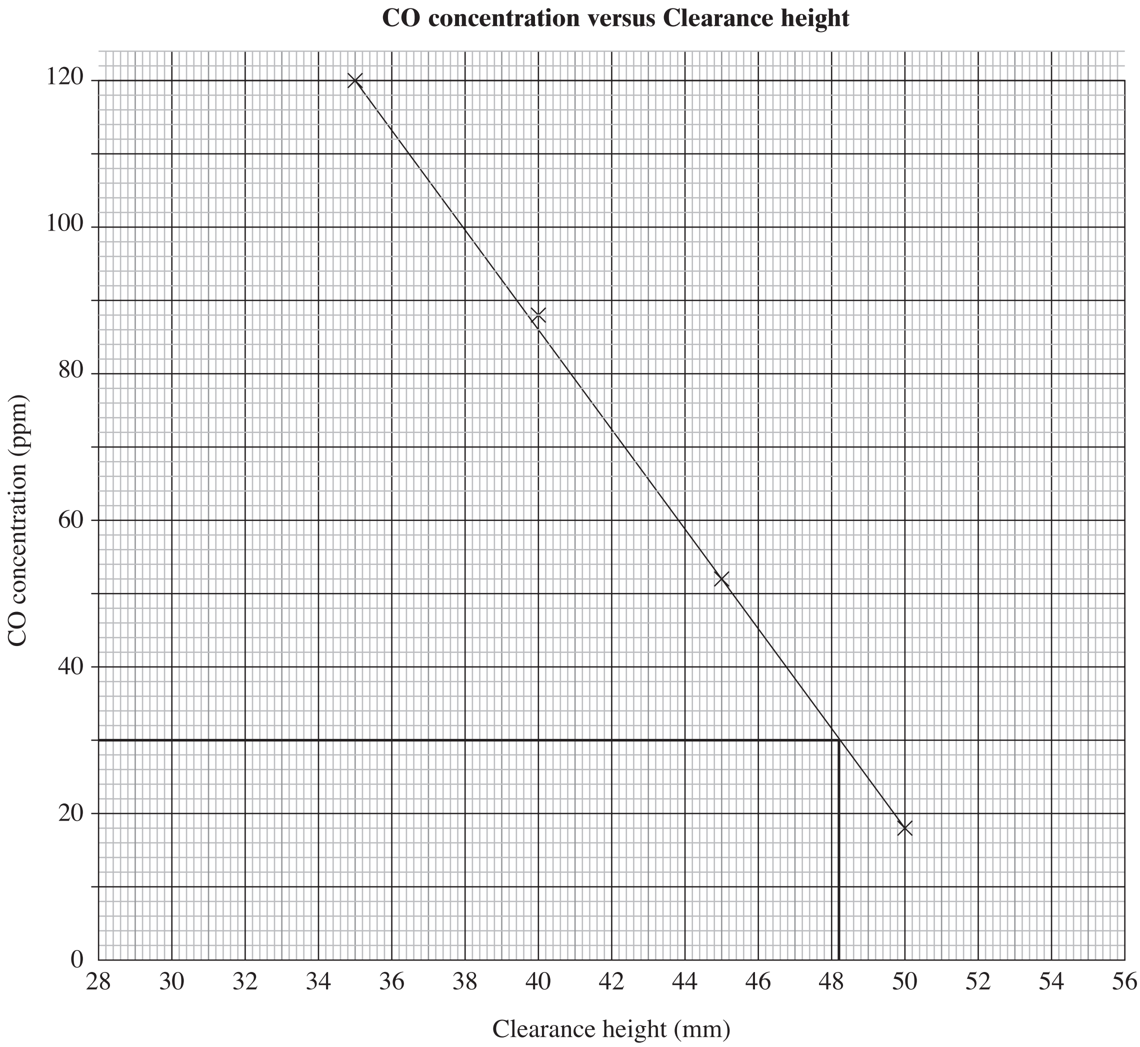
$M(HC_6H_7O_6) = 176.124$ g/mol

$m(HC_6H_7O_6) = n.M = (0.0234)(176.124) = 4.12$ g

$\%(HC_6H_7O_6) = \frac{4.12}{100} \times \frac{100}{1} = 4.12$ %w/w *(4 marks)*

Question 28 (Total 8 marks)

(a)



Labelled axes with units;

correct plotting of data points;

straight line of best fit *(3 marks)*

(b) Minimum clearance height = 48.2 mm (based on line of best fit in part (a)) *(1 mark)*

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(c) The minimum safe clearance height of 48.2 mm (from (b)) would result in an efficiency of 37.2% as the second data table shows that the % efficiency decreases by 4% for each millimetre clearance height.

$M(C_4H_{10}) = (12.01 \times 4) + (1.008 \times 10) = 58.12$ g/mol

$n(C_4H_{10}) = \frac{m}{M} = \frac{15.0}{58.12} = 0.258$ mol

37.2% efficiency, the heat released to heat the water $= \left(\frac{37.2}{100}\right) \times (0.258 \times 2877)$

$= 276.1 \text{ kJ} = 2.761 \times 10^5 \text{ J}$

Density of water = 1.0 kg/L at 20 °C

Mass of water = $DV = 1.0 \times 1.0 = 1.0$ kg

$q = mc\Delta T$

$2.761 \times 10^5 = (1.0)(4.18 \times 10^3)(\Delta T)$

$\Delta T = 66.1°$

Highest temperature = 20 + 66.1 = 86.1 = 86 °C (2 sig. figs) *(4 marks)*

Question 29 (Total 7 marks)

(a) Anhydrous sodium carbonate (Na_2CO_3) is a common primary standard base.
It is a stable, pure solid of known composition.

It is soluble in water. It is readily dried in a drying oven or desiccator and it is not hygroscopic. *(2 marks)*

(b) Mean titre $= \frac{(21.65 + 21.70 + 21.60)}{3} = 21.65$ mL

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

$n(Na_2CO_3) = cV = (0.1050)(0.02500) = 2.625 \times 10^{-3}$ mol

Reaction stoichiometry: $Na_2CO_3 : HCl = 1:2$

$n(HCl) = 2 \times 2.625 \times 10^{-3} = 5.250 \times 10^{-3}$ mol

$c(HCl) = \frac{n}{V} = 5.250 \times \frac{5.250 \times 10^{-3}}{0.021\,65} = 0.2425$ mol/L *(3 marks)*

(c) This is a weak base—strong acid titration and the equivalence points occur at a pH less than 7.

Phenolphthalein changes colour between pH 10 and 8.3.

Thus the end point will occur before the equivalence point and the volume of acid will be less than that required for equivalence. The calculated HCl concentration will be greater than the correct concentration. *(2 marks)*

Question 30 (Total 7 marks)

Fossil fuel combustion

Fossil fuels include coal, crude oil and natural gas. Coal consumption has tripled and crude oil consumption has doubled worldwide in the last 50 years. Natural gas consumption has quadrupled around the world in this time. Coal is burned to generate electricity. Crude oil is refined to produce fuels such as petrol, diesel and kerosene to power cars, trucks, trains and aeroplanes. Natural gas is burnt to power turbines to produce electricity. All these fossil fuels produce carbon dioxide on combustion.

Octane (petrol component): $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

Methane (natural gas component): $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Atmospheric carbon dioxide levels

In the last 50 years the atmospheric concentration of carbon dioxide has been measured and the data shows the concentration has risen from 320 ppm to 400 ppm due to increased levels of fossil fuel combustion. This is the result of population growth around the world and the increased use of electricity and vehicles.

Carbon dioxide is a greenhouse gas. This means that these molecules absorb solar radiation and reradiate it in the form of infrared radiation in the troposphere. This radiation warms the Earth's surface as infrared radiation is converted to heat. This heating is vital to life forms on Earth. Increasing carbon dioxide levels produce an enhanced greenhouse effect and increases in temperature.

Global air and ocean temperatures

In the last 50 years scientific measurements show that the average global air temperatures have risen by 1 °C . This is attributed to the enhanced greenhouse effect. This rate is approximately double the rise over the previous 50 years.

In the last 50 years average global ocean temperatures have risen by approximately 0.7 °C. This temperature increase in the oceans has led to sea-level rises due to the melting of polar ice and glaciers.

Volume of carbon dioxide dissolved in the oceans

Carbon dioxide dissolves in water according to the following equilibria:

$CO_2(g) \rightleftharpoons CO_2(aq)$

$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

Increased ocean temperatures reduce the solubility of carbon dioxide as the dissolution equilibria are exothermic and shift to the left as temperature increases.

The increase in the concentration of atmospheric carbon dioxide has led to increased levels of carbon dioxide in the ocean. This increase caused each of the above equilibria to shift to the right as predicted by Le Chatelier's Principle.

The net effect of these changes to the equilibria has been investigated and there has been an overall increase in hydronium ion concentration which in turn has increased ocean acidity. Since the industrial revolution which began around 200 years ago, the pH of the oceans has decreased from 8.2 to 8.1. This represents an approximate 29% increase in hydronium ion concentration. This acidification has had an effect on aquatic organisms. Coral bleaching on the Great Barrier Reef is partly attributed to this pH change. The formation of calcium carbonate shells in molluscs will also be affected by a lower pH.

Conclusion

The only effective way to reduce greenhouse emissions is to use non-carbon energy sources such as solar energy, wind energy and hydroelectricity. The electrical energy generated by these energy sources can be transformed and stored as chemical potential energy in batteries and used to power our vehicles and appliances. The transition from fossil fuels to renewable energy sources cannot occur quickly as national economies need time to adapt. Continued scientific and engineering research and development is required. *(7 marks)*

Question 31 (Total 7 marks)

Solubility product constant (K_{sp})

$$n(\text{PbBr}_2) = \frac{m}{M} = \frac{0.973}{(207.2 + (2 \times 79.90))} = 2.65 \times 10^{-3} \text{ mol per 100 mL water solubility}$$

$$= \frac{2.65 \times 10^{-3}}{0.100} = 2.65 \times 10^{-2} \text{ mol/L}$$

$Pb^{2+}(aq) + 2Br^{-}(aq) \rightarrow PbBr_2(s)$

Stoichiometry: $Pb^{2+} : Br^{-} = 1 : 2$

$[Pb^{2+}] = 2.65 \times 10^{-2}$ mol/L; $[Br^{-}] = 5.30 \times 10^{-2}$ mol/L

$K_{sp} = [Pb^{2+}][Br^{-}]^2$

$= (2.65 \times 10^{-2})(5.30 \times 10^{-2})^2 = 7.44 \times 10^{-5}$

Precipitation

$n(Br^{-}) = cV = (0.0010)(0.100) = 1.0 \times 10^{-4}$ mol

$n(Pb^{2+}) = cV = (0.0010)(0.100) = 1.0 \times 10^{-4}$ mol

On mixing, the number of moles of bromide ions is limiting based on the stoichiometry and all the bromide ions will react to form lead (II) bromide.

$$\frac{1.0 \times 10^{-4}}{2} = 5.00 \times 10^{-5} \text{ mol of lead (II) bromide}$$

$m(PbBr_2) = n.M = (5.0 \times 10^{-5})(207.2 + (2 \times 79.90)) = 0.0184$g

On mixing, $V = 200$ mL; mass of solution = 200 g

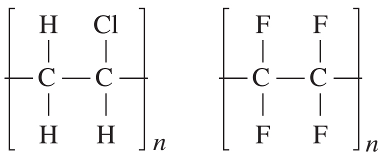
Answer 31 continues

Answer 31 (continued)

As the solubility of lead (II) bromide is $\frac{0.973\text{ g}}{100\text{ g}}$, then all the 0.0184 g of lead (II) bromide will dissolve in the 200 g of solution and no precipitate will form. No dynamic equilibrium can form. *(7 marks)*

Question 32 (Total 6 marks)

Both LDPE and PTFE are addition polymers. The LDPE is formed from ethylene monomers using the radical initiator method. PTFE is formed from tetrafluoroethylene monomers using the radical initiator method. The structures of each polymer are shown below.



LDPE PTFE

The following table compares the properties of these two polymers.

Low density polyethylene (LDPE):	*Polytetrafluoroethylene (PTFE)*:
LDPE has many short branching side chains. These side chains cause disruption in the packing of the polymer chains in the crystal lattice. LDPE molecules have low flexible strength. Their flexibility is due to weakening of the dispersion forces between the polymer chains.	PTFE chains are unbranched with polymer chains forming structures which pack tightly together. PTFE has high flexible strength with a low friction surface. PTFE has a high melting point and high thermal stability.

The following table compares the uses of these two polymers.

Low density polyethylene (LDPE):	*Polytetrafluoroethylene (PTFE)*:
Due to its flexibility, LDPE is commonly used to make plastic bags, squeeze bottles, electrical insulation and plastic food cling wrap.	The high thermal stability and low friction make PTFE an excellent coating for non-stick frypans. The low friction and inert properties are used as well in industrial coatings such as on gears.

(6 marks)

Question 33 (Total 6 marks)

The tetraaquazinc (II) ion ($Zn(H_2O)_4^{2+}$) is a Brønsted–Lowry acid:

$$Zn(H_2O)_4^{2+}(aq) + H_2O(l) \rightleftarrows Zn(H_2O)_3OH^+(aq) + H_3O^+(aq)$$

$Zn(H_2O)_3OH^+$ is the weak conjugate base whereas the hydronium ion that forms makes the solution acidic as hydronium ions are strong acids.

The formate (or methanoate) ion ($HCOO^-$) is a Brønsted–Lowry base.

$$HCOO^-(aq) + H_2O(l) \rightleftarrows HCOOH(aq) + OH^-(aq)$$

The formic acid that forms is a weak conjugate acid whereas the hydroxide ion that forms makes the solution basic as hydroxide ions are strong bases.

Laboratory test:

1. Prepare 0.10 mol/L solutions of zinc sulfate and potassium formate.
2. Place 5 mL of zinc sulfate solution and 5 mL of potassium formate solution in separate test tubes.
3. Add drops of universal indicator to each solution. Note the colour of the indicator.
4. Use a pH colour card to determine the approximate pH of each solution.

Typical results:

Zinc sulfate solution: UI = orange-yellow: pH $\sim$ 5

Potassium formate solution: UI = greenish-blue: pH $\sim$ 8 *(6 mark)*

Question 34 (Total 6 marks)

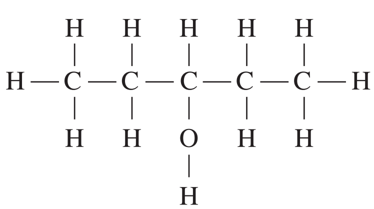
The molecular formula of X indicates that it could be an alkanol.

Secondary alkanols are oxidised by strong oxidants such as acidified potassium dichromate to form alkanones whereas primary alkanols are oxidised to form alkanoic acids. As there is no effervescence of Y with sodium carbonate solution then Y is not an alkanoic acid.

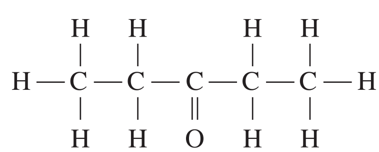
Thus X is a secondary alkanol and Y is an alkanone.

The following structures (pentan-3-ol and pentan-3-one) are consistent with the three peaks in each C-13 NMR spectrum as there are three different chemical environments for the carbon atoms.

Pentan-2-ol would show 3 peaks and pentan-2-one would show 3 peaks in their C-13 NMR spectra.



X: pentan-3-ol



Y: pentan-3-one

(6 marks)

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