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VCE Chemistry ½

Solubility & Precipitation [1.9]

Homework Solutions

Homework Outline:

Section A: Compulsory Questions (53 Marks)

Sub-Section: Explain the Process by Which Ionic Compounds Dissolve in Water with Reference to Ion-Dipole Bonding

Question 1 (2 marks)

Consider a Na^+ ion that is placed right next to a molecule of H_2O. Explain how ion-dipole bonds between these two are formed.

As water is a dipole, the negative end (oxygen) of the molecule will be attracted towards the cation of Na^+. This creates an ion-dipole bond due to the resulting electrostatic attraction.

Question 2 (3 marks)

Between ion-dipole bonds, ionic bonds and dipole-dipole attractions, rank these in terms of increasing strength, giving your justification for your answer.

Dipole-dipole attractions would be the weakest out of the list due to the attraction existing between partial charges only. The next strongest one would be ion-dipole bonds because it is an electrostatic attraction that exists between a full charge (ion) and a partial charge. Then, ionic bonds would be the strongest due to it being an electrostatic attraction between two full charges, i.e. a cation and an anion.

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Question 3 (4 marks)

Consider the substance NaCl. Show, with the use of diagrams, how NaCl would dissolve in water and explain the process.

NaCl would dissolve in water by first being surrounded by water molecules, then as the water is a dipole, the negative end of the water would be attracted to the cation in NaCl, the Na^+, and the positive end (H) would be attracted to the anion Cl^-. The water molecules will form ion-dipole bonds with their respective ions and hence overwhelm the ionic bonds in the NaCl, thereby disassembling the lattice, causing the NaCl to dissolve.

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Sub-Section: Write Balanced Equations for Ionic Compounds Dissociating/Ionising in Water

Question 4 (2 marks)

Write the ionisation reactions for the following compounds.

a. LiF. (1 mark)

$LiF(l) \rightarrow Li^+(aq) + F^-(aq)$

b. NaCl. (1 mark)

$NaCl(l) \rightarrow Na^+(aq) + Cl^-(aq)$

Question 5 (4 marks)

Write the ionisation reactions for the following.

a. K_2SO_4. (2 marks)

$K_2SO_4(s) \rightarrow 2K^+(aq) + SO_4^{2-}(aq)$

b. H_2CO_3. (2 marks)

$H_2CO_3(l) \rightarrow 2H^+(aq) + CO_3^{2-}(aq)$

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Question 6 (4 marks)

Consider a certain sample of Na_2SO_4. Explain how it is dissolved in water, including the reaction that represents this process.

The Na_2SO_4 lattice would first be surrounded by water molecules, and as the water molecules are dipoles, the positive end (H) will be attracted towards the anion component, SO_4^{2-}, and the negative end (O) will be attracted towards the Na^+ ions. As Na_2SO_4 have strong ionic bonds, multiple water molecules will surround the lattice and form multiple ion-dipole bonds, overcoming the strong ionic bonds and hence dissolving the lattice.

$$Na_2SO_4(s) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq)$$

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Sub-Section: Identify Which Compounds Will or Will Not Dissolve in Water, with Reference to SNAPE and/or Solubility Tables

Question 7 (4 marks)

For each of the following compounds, determine whether they are soluble in water.

a. HNO_3. (1 mark)

Soluble

b. C_2H_6. (1 mark)

Insoluble

c. NH_4Cl. (1 mark)

Soluble

d. NaF. (1 mark)

Soluble

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Question 8 (4 marks)

Referring to the following solubility table, determine whether the following compounds are soluble in H_2O.

Solubility table

Salts	Soluble	Insoluble
Sodium	All	None
Potassium		
Ammonium		
Nitrate		
Ethanoate		
Bromide, Chloride, Iodide	Most are soluble.	Lead(ll), Silver,$CuBr_2$, CuI_2
Sulphate	Most soluble.	Barium, Calcium, Lead(ll), Silver
Carbonate	Group 1 ions, ammonium	Most are insoluble.
Phosphate	Group 1 ions. ammonium	Most are insoluble.
Hydroxide	Group 1 ions. ammonium	Most are insoluble.

a. $PbBr_2$. (1 mark)

Insoluble

b. $CuSO_4$. (1 mark)

Soluble

c. $Pb_3(PO_4)_2$. (1 mark)

Insoluble

d. $Al(OH)_3$. (1 mark)

Insoluble

Question 9 (4 marks)

Consider the molecule of AgCl.

a. Determine whether it is soluble in water. (1 mark)

No

b. Explain your answer with reference to intermolecular bonding. (3 marks)

This means that when AgCl is put into water, its internal ionic bonding that holds the lattice together is stronger than the ion-dipole bonds that each respective ion forms with the dipoles of water. Because water cannot overcome the ionic bonding, therefore AgCl is insoluble in water.

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Sub-Section: Write Full & Ionic Equations for Precipitation Reactions

Question 10 (4 marks)

Identifying spectator ions from equations already written and identifying whether the ionic or full equation is given and explaining their difference maybe.

For each of the following, identify their spectator ions and whether it is an ionic equation or a full equation.

a. $2NaCl(aq) + Fe(NO_3)_2(aq) \rightarrow 2NaNO_3(aq) + FeCl_2(s)$

i. Type of reaction. (1 mark)

Full equation.

ii. Spectator ions. (1 mark)

Na^+ and NO_3^-.

b. $2Ag^+(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)$

i. Type of reaction. (1 mark)

Net Ionic Equation.

ii. Spectator ions. (1 mark)

None

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Question 11 (4 marks)

For each of the following, state whether a precipitate will form and if so, write its identity and state any spectator ions, if applicable.

a. NaBr and $Pb(NO_3)_2$.

i. Precipitate. (1 mark)

$PbBr_2$

ii. Spectator ions. (1 mark)

Na^+ and NO_3^-.

b. KCl and $NaNO_3$.

i. Precipitate. (1 mark)

None

ii. Spectator ions. (1 mark)

K^+, Cl^-, Na^+ and NO_3^-.

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Question 12 (6 marks)

For the following, write their fully balanced precipitation reactions from the following reactants. Make sure to identify any spectator ions, and write the net ionic equations as well.

a. Sodium bromide and Lead (II) nitrate. (2 marks)

$2NaBr(aq) + Pb(NO_3)_2(aq) \rightarrow PbBr_2(s) + 2NaNO_3(aq)$
Spectator Ions: Na^+ and NO_3^-
Net Ionic: $Pb^{2+}(aq) + 2Br^-(aq) \rightarrow PbBr_2(s)$

b. Potassium dichromate, $K_2Cr_2O_7$ and silver sulphate. (2 marks)

$K_2Cr_2O_7(aq) + Ag_2SO_4(aq) \rightarrow Ag_2Cr_2O_7(s) + K_2SO_4(aq)$
Spectators: K^+ and SO_4^{2-}
Net ionic equation: $2Ag^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow Ag_2Cr_2O_7(s)$

c. Aluminium (III) nitrate and potassium sulphide. (2 marks)

$2Al(NO_3)_3(aq) + 3K_2S(aq) \rightarrow Al_2S_3(s) + 6KNO_3(aq)$
Spectator: K^+ and NO_3^-
Net Ionic: $2Al^{3+}(aq) + 3S^{2-}(aq) \rightarrow Al_2S_3(s)$

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Sub-Section: The 'Final Boss'

Question 13 (8 marks)

You are a scientist working in a chemical research lab investigating the properties of a newly synthesised compound. You are given an unknown white crystalline solid, labelled Compound *X*, and are tasked with determining its solubility in water and the potential reactions it might undergo.

Observations:

- Compound *X* is either Zinc Oxalate (ZnC_2O_4) or Silver Nitrate ($AgNO_3$).
- Compound *X* can be dissolved in water.
- You are also provided with solutions of potassium sulphate K_2SO_4 and ammonium carbonate $(NH_4)_2CO_3$ to conduct precipitation reactions.

a. Predict whether zinc oxalate or silver nitrate would dissolve in water and therefore identify Compound *X*'s identity. (2 marks)

Silver Nitrate has a SNAPE ion and therefore will dissolve in water, therefore *X* is Silver Nitrate.

b. Write the dissolution reaction for Compound *X* in water and explain the process of how it will go through this process. (3 marks)

$$AgNO_3(aq) \rightarrow Ag^+(aq) + NO_3^-(aq)$$

First, the strontium nitrate will be surrounded by water molecules where the water's dipoles will form ion-dipole bonds with the respective ions that exist in the strontium nitrate. These ion-dipole bonds will then eventually overpower the internal ionic bonding that exists in strontium nitrate's ionic lattice and hence the lattice will dissolve, allowing the ions to be pulled apart and therefore dissolve in water.

c. Now, Compound *X* is mixed with a solution of potassium sulphate.

i. Fully balanced reaction. (2 marks)

$AgNO_3(aq) + K_2SO_4(aq) \rightarrow Ag_2SO_4(s) + 2KNO_3(aq)$

ii. Does a precipitate form? If so, what is it? (1 mark)

Ag_2SO_4

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Section B: Supplementary Questions (62 Marks)

Sub-Section: Explain the Process by Which Ionic Compounds Dissolve in Water with Reference to Ion-Dipole Bonding

Question 14 (2 marks)

Explain why NaCl dissolves in water but not in another molecule like hexane, C_6H_{14}.

NaCl dissolves in water because water is polar and has dipoles whereas hexane does not. Due to hexane's inability to have dipoles, therefore it cannot form ion-dipole bonds to pull apart and dissolve the NaCl whereas H_2O can.

Question 15 (3 marks)

Explain why hydrogen bonding is stronger than dipole-dipole interactions but weaker than ion-dipole bonds.

Hydrogen bonding is stronger than dipole dipole as it contains stronger partial charges that are closer together due to the exposed hydrogen. However, it is weaker than ion-dipole bonds as ion-dipole bonds contain a partial and a full charge but hydrogen bonds only have partial charges.

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Question 16 (4 marks)

Aside from understanding intermolecular bonds themselves, we also need to understand how they compare with each other.

a. Explain why ion-dipole bonds are stronger than dipole-dipole interactions. (2 marks)

Ion-Dipole bonds have an electrostatic attraction between a partial charge and a full charge whereas dipole-dipole interactions only occur between partial charges. Hence, ion-dipole bonds will be stronger due to their greater charge

b. Would this behaviour be the same as when we compare ion-dipole bonds with ionic bonding? Justify your answer. (2 marks)

No, because ionic bonding is between two full charges whereas ion-dipole bonds involve a partial charge, hence, ionic bonding would be stronger than ion-dipole bonds. Furthermore, ionic bonding is intramolecular and not intermolecular

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Question 17 (7 marks)

Consider the compound of calcium nitrate.

a. Write its dissolution reaction in water. (2 marks)

$Ca(NO_3)_2\ (s) \rightarrow Ca^{2+}\ (aq) + 2NO_3^-\ (aq)$

b. Explain the bonding that the components of this substance undergo with water when it is dissolved. (2 marks)

Ion-dipole bonding where the Ca^{2+} is attracted to the oxygen end of the water as it is partially negative and the NO_3^- is attracted to the positive end of water, the Hydrogen end.

c. Do you expect the bonds between this compound and water to be stronger or weaker than the bonds between water and itself? Explain your answer. (3 marks)

As the bonds between this compound and water are ion dipole bonds, and the bonds between water and itself are considered to be hydrogen bonding because it is intermolecular bonding, hydrogen bonding only involves partial charges. Whereas the ion dipole bonding between the compound and the water is stronger than the hydrogen bonding hence it is stronger overall.

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Sub-Section: Write Balanced Equations for Ionic Compounds Dissociating/Ionising in Water

Question 18 (1 mark)

What is the difference between solvent and solute?

Solute is the substance that is being dissolved, whereas solvent is the liquid the solute is being dissolved in.

Question 19 (3 marks)

Write the dissolution reactions for the following.

a. NH_4NO_3. (1 mark)

$NH_4NO_3\ (l) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq)$

b. $Al_2(SO_4)_3$. (2 marks)

$Al_2(SO_4)_3\ (s) \rightarrow 2Al^{3+}\ (aq) + 3SO_4^{2-}\ (aq)$

Question 20 (3 marks)

Describe how the compound $CaCO_3$ would dissolve in water, including writing the reaction that represents this process.

$CaCO_3$ would first be surrounded by H_2O molecules, and as the H_2O molecules are dipoles, they will be attracted towards the cation component (Ca^{2+}) and the anion component CO_3^{2-} . Then the H_2O would form ion-dipole bonds with the respective ions, and eventually these bonds will overcome the ionic bond that holds $CaCO_3$ together and thus the ions will separate and dissociate. Once they dissociated and become surrounded by water molecules, $CaCO_3$ would have become completely dissolved

Question 21 (7 marks)

Consider the molecule HCl.

a. Describe how a molecule of HCl would dissolve in water, including writing the reaction that represents this process. (3 marks)

HCl would enter water and the water molecules will align its respective dipole with the dipoles of the HCl molecule, H being positive and Cl being negative. The water molecules will then use the dipole-dipole attraction to separate the HCl entirely and cause them to ionise into H^+ and Cl^-. Afterwards, the ions will form ion-dipole bonds with H_2O to become fully dissolved.

b. What is the difference between HCl before and after the process detailed in **part a.**? Justify your answer. (2 marks)

HCl was previously undergoing covalent bonding, but after dissociating it is technically considered ionic because the H and the Cl have been ionised

c. Would you expect either one of these to be electrically conductive? Explain. (2 marks)

Only the HCl dissolved in water would be electrically conductive because they have free moving charges which allow for transfer of charge.

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Sub-Section: Identify Which Compounds Will or Will Not Dissolve in Water, with Reference to SNAPE and/or Solubility Tables

Question 22 (2 marks)

For each of the following, determine whether they are soluble or not, giving justification.

a. $Fe(NO_3)_2$. (1 mark)

Soluble as NO_3^- is a SNAPE ion

b. Na_2CO_3. (1 mark)

Soluble as Na^+ is a SNAPE ion

Question 23 (2 marks)

Suggest something the SNAPE rule does not tell you about the solubility of compounds.

SNAPE does not tell you the extent to which a substance is soluble, it only says whether it generally is or is not.

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Question 24 (3 marks)

Determine whether the following are soluble, referring to solubility tables.

a. Lead (II) Sulphate. (1 mark)

Insoluble

b. Potassium Carbonate. (1 mark)

Soluble

c. Silver Chloride. (1 mark)

Insoluble

Question 25 (7 marks)

Consider the compound of $Ni(OH)_2$.

a. Is the molecule soluble in water? (1 mark)

No

b. According to your answer to **part a.**, explain how this occurs with reference to intermolecular bonding. (3 marks)

The ionic bond that exists between OH^- ions and NI^{2+} ions are very strong and the ion-dipole bonds that are formed between the water molecules and their respective ions are not strong enough to overcome the aforementioned ionic bonds.

c. Now, given the molecule of $NiSO_4$, would your answer change? If so, explain why. (3 marks)

Yes $NiSO_4$ would be soluble according to solubility tables. This means the ion-dipole bonds will now be strong enough to overpower the incumbent ionic bonds in the lattice of $NiSO_4$ and therefore dissolve in water

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Sub-Section: Write Full & Ionic Equations for Precipitation Reactions

Question 26 (2 marks)

For the reaction below, explain whether a precipitate is formed.

$$HCl\,(aq) + NaOH\,(aq) NaCl\,(aq) + H_2O\,(l)$$

A precipitate is formed was water is considered a precipitate as the ions have combined to form a new compound that is not itself soluble in water.

Question 27 (4 marks)

For the following full reactions, write the ionic equations and identify the spectator ions, if any.

a. $MgBr_2 + K_2SO_4 \rightarrow MgSO_4 + 2KBr$.

i. Ionic Equation. (1 mark)

$Mg^{2+}(aq) + SO_4^{2-}(aq) \rightarrow MgSO_4(s)$

ii. Spectator ions. (1 mark)

K^+ and Br^-

b. $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$

i. Ionic Equation. (1 mark)

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

ii. Spectator ions. (1 mark)

Na^+ and Cl^-.

Question 28 (6 marks)

For each of the following compounds, write the reaction that will occur between them and specify any precipitate and spectator ions.

a. Aluminium phosphate and silver (I) nitrate.

i. Full reaction. (1 mark)

$AlPO_4\ (aq) + AgNO_3\ (aq) \rightarrow Ag_3PO_4\ (s) + Al(NO_3)_3\ (aq)$

ii. Spectator ions. (1 mark)

Al^{3+} and NO_3^-.

iii. Precipitate. (1 mark)

Ag_3PO_4

b. Calcium chloride and sodium carbonate.

i. Full reaction. (1 mark)

$CaCl_2\ (aq) + Na_2CO_3\ (aq) \rightarrow CaCO_3\ (s) + 2NaCl\ (aq)$

ii. Spectator ions. (1 mark)

Na^+ and Cl^-.

iii. Precipitate. (1 mark)

$CaCO_3\ (s)$

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Question 29 (6 marks)

Consider a beaker of H_2O that has magnesium nitrate dissolved in it.

a. Write the dissolution reaction for magnesium nitrate. (2 marks)

$Mg(NO_3)_2\ (aq) \rightarrow Mg^{2+}\ (aq) + 2NO_3^-\ (aq)$

b. As we add more magnesium nitrate into the beaker, do we expect it to become easier or harder to dissolve? (2 marks)

It would become harder to dissolve because, there is less and less water molecules to separate and surround the ions of Magnesium nitrate

c. If we put a few droplets of sodium iodide into the solution, write the reaction that will occur, including states. (2 marks)

$Mg(NO_3)_2\ (aq) + 2NaI\ (aq) \rightarrow MgI_2\ (s) + 2NaNO_3\ (aq)$

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