FACTFILE: GCSE CHEMISTRY: UNIT 1.10

Rewarding Learning

Solubility

Learning outcomes

Students should be able to:

1.10.1 define solubility as the mass of solid required to saturate 100 g of water at a particular temperature;

1.10.2 use given data to calculate solubility values;

1.10.3 experimentally determine the solubility of a solid in water;

1.10.4 demonstrate knowledge and understanding that a saturated solution is one in which no more solute will dissolve at that temperature **and understand that when a hot concentrated solution is cooled some of the solute will be deposited, and calculate the mass of solute deposited**;

1.10.5 draw and interpret solubility curves (graph of solubility in g/100 g water against temperature in °C); and

1.10.6 demonstrate knowledge and understanding that the solubility of gases decreases as temperature increases whereas the solubility of a solid generally increases as temperature increases.

What is solubility?

Solubility is the mass of solute required to saturate 100 g of water at a particular temperature.

The units of solubility are g/100 g of water.

Worked example

(a) Calculate the solubility when 42 g of potassium nitrate saturates 50 g water at 50 °C
(b) Calculate the solubility when 75 g of potassium nitrate saturates 150 g of water at 60 °C

Answer

(a) At 50 °C 42 g saturates 50 g water
At 50 °C 42 x 2 g saturates 100 g water
At 50 °C 84 g saturates 100 g water
The solubility is 84 g/100 g water at 50 °C

(b) At 60 °C 75 g saturates 150 g water
At 60 °C 75 x 2/3 g saturates 100 g water
At 60 °C 50 g saturates 100 g water
The solubility is 50 g/100 g water at 60 °C

What is a saturated solution?

A saturated solution is one in which no more solute will dissolve at that temperature.

Worked example

Potassium nitrate has solubility 48 g/100 g water at 30 °C. A mixture contains 30 g of KNO_3 dissolved in 50 g water at 30 °C. Is this mixture a saturated solution?

Answer

At 30 °C 48 g of KCl saturates 100 g water
The mixture contains 50 g water

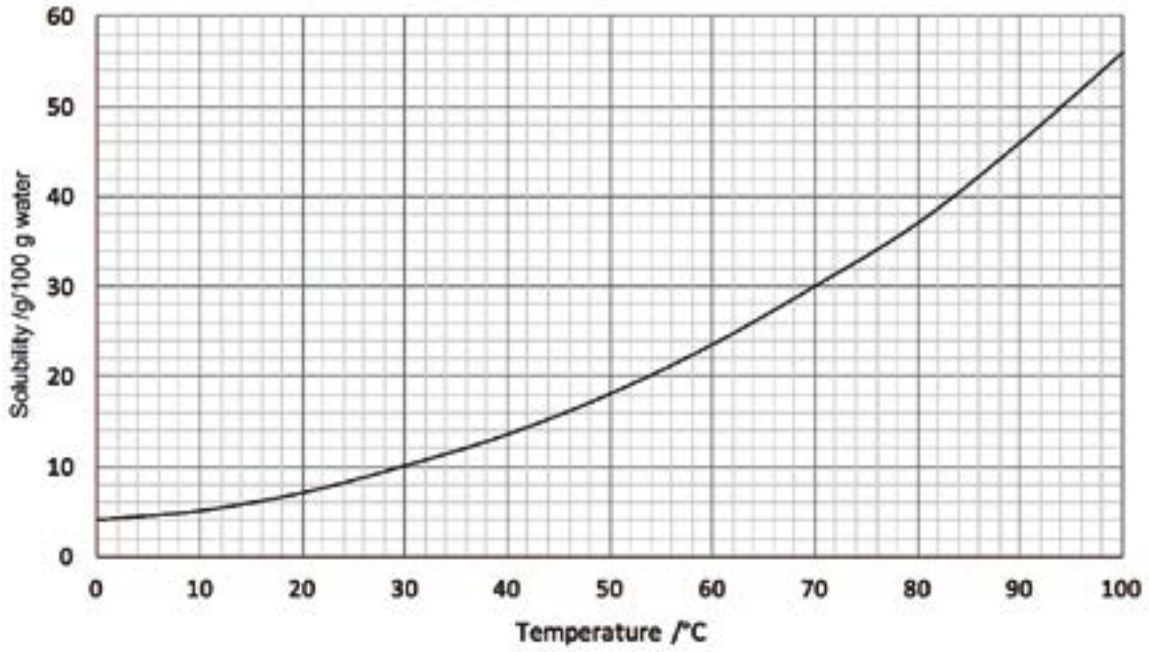
At 30 °C 24 g of KCl saturates 50 g water. The mixture contains 30 g of KCl in 50 g water so it is **saturated** – there will be 30 – 24 g = 6 g of potassium nitrate not dissolved.

What is a solubility curve?

A solubility curve is a graph of solubility in g/100 g water (y axis) against temperature in °C (x axis).

The **solubility of a solid increases** as **temperature increases** and the **solubility of a gas decreases** as **temperature increases**.

The solubility curve for potassium chlorate is shown below.



The temperature axis on a solubility curve often starts at 0 °C and stops at 100 °C, as water is a liquid over this range. Each point along the curve represents a saturated solution at that temperature. Each point below the curve represents an unsaturated solution.

[Higher Tier only] When a **hot concentrated solution of a salt is cooled**, then some of the **solute** will be **deposited**. This is because the solubility of a solid *decreases* when the temperature *decreases*, and some of the solid will crystallise out and be deposited.

You must be able to calculate the mass of solid deposited when a hot concentrated solution is cooled from a high temperature to a lower temperature. The difference between the solubility values at each temperature gives the mass of solid deposited.

Worked example

(a) Using the graph above determine the mass of solid which will be deposited when a saturated solution containing 100 g of water is cooled from 80 °C to 40 °C

Answer

- Use the graph to find the solubility at each temperature -this gives the mass of solid present in 100 g water
- Subtract the solubility values to find the mass deposited on cooling the 100 g of solution

Temperature	**80 °C**	**40 °C**
Solubility in g/100 g	37	14
Subtract solublities	37 – 14 = 23 g deposited in 100 g water	

Remember – never subtract *temperature* values.

(b) Using the graph determine the mass of solid which will be deposited when a saturated solution containing 25 g of water is cooled from 90 °C to 60 °C

Answer

The method is the same, however there is only 25 g of water in the solution, so divide the answer by 4.

Temperature	**90 °C**	**60 °C**
Solubility in g/100 g (from graph)	46.0	23.5
Subtract masses	46.0 – 23.5 = 22.5 g deposited in 100 g water	
Scale answer for 25 g of solution	22 ÷ 4 = 5.625 g deposited in 25 g water	

If this question had asked for the mass deposited in a larger mass of water in the solution than 100 g, for example 200 g, then scale your answer by multiplying. For this example the answer would be 45 g/200 g water.

(c) Using the graph to determine the mass of solid which will crystallise when a solution which is not saturated, containing 9 g of potassium chlorate dissolved in 50 g water is cooled from 60 °C to 40 °C

Answer

- The solution is not saturated at 60 °C. it contains 9 g in 50 g water.
- Find the solubility at the lower temperature
- There is only 50 g of water so divide the solubility value by 2
- Subtract the masses

Temperature	**60 °C**	**40 °C**
Solubility	Not saturated	14 g/100 g water
Scale for 50 g water	9 g/50 g water	7 g/50 g water
Subtract masses	9 – 7 = 2 g deposited in 50 g water	

How can solubility of a solid be determined experimentally?

- Using an electronic balance weigh out a known mass of solid into a dry boiling tube
- Using a measuring cylinder add 10 cm^3 of water to the boiling tube
- Place a thermometer in the boiling tube
- Place the boiling tube in a water bath and heat, stirring gently with a thermometer until the solid completely dissolves
- Remove the boiling tube from the water bath and allow to cool, stirring continuously until tiny flakes of solid crystallise from the solution. Record this temperature. At this temperature the mass of solid is no longer completely soluble and some starts to crystallise out
- The experiment can be repeated using different masses of solid and a graph of solubility against temperature can be drawn.

Revision Question

1(a) The table below shows values for the solubility of copper(II) sulfate

Temperature (°C)	0	20	40	60	80	100
Solubility (g/100 g water)	14	20	28	40	56	77

(i) Explain what is meant by the term solubility

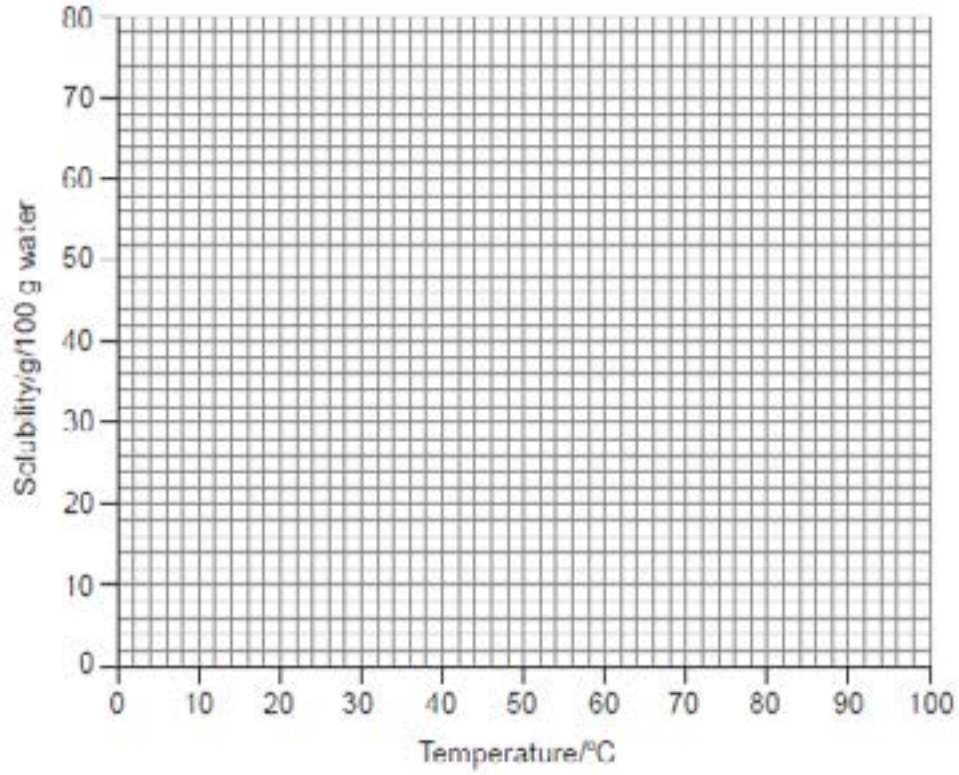
_____

_____

_____

_____ [4]

(ii) Use the data in the table to plot a solubility curve for copper(II) sulfate on the axes below.



(b) Use the graph in **(a)(ii)** to answer the following questions.

(i) What is the maximum mass of copper(II) sulfate which will dissolve in 10 g of water at 70 °C?

Mass of copper(II) sulfate = _____ g [2]

(ii) Calculate the mass of copper(II) sulfate which will crystallise out of solution if a saturated solution of copper(II) sulfate containing 200 g of water is cooled from 75 °C to 45 °C.

Mass of copper(II) sulfate = _____ g [4]