Solutions and Solubility Review

Answer Section

SHORT ANSWER

1. ANS:

   Positive potassium ions attract the negatively charged oxygen atoms of water molecules, and negative chloride ions attract the positively charged hydrogen atoms of the water molecules. The KCl is completely dissociated when all of the potassium and chloride ions have become hydrated or surrounded by water molecules.

   PTS: 1 REF: K/U OBJ: 6.2 STA: SS1.02

2. ANS:

   Sodium nitrate is an ionic solid and will dissolve more easily as temperature increases because warmer water has greater heat energy to overcome the attractive forces between the sodium and nitrate ions. Oxygen is a gas and its molecules must gain more energy to overcome the attractive forces of the water molecules and escape the solution.

   PTS: 1 REF: K/U OBJ: 6.2 STA: SS1.02

3. ANS:

   Dilute solutions contain very little dissolved solute in the solvent. Concentrated solutions contain a relatively large amount of dissolved solute in the solvent.

   PTS: 1 REF: K/U OBJ: 6.3 STA: SS2.01

4. ANS:

   Air is a solution of nitrogen, oxygen, and trace amounts of other gases.

   PTS: 1 REF: K/U OBJ: 6.1 STA: SS3.01

5. ANS:

Compound	**Soluble or insoluble**
(a) PbI_2	insoluble
(b) $KClO_3$	soluble
(c) $CaCO_3$	insoluble
(d) $BaSO_4$	insoluble

PTS: 1 REF: I OBJ: 7.1 | 7.5 STA: SS1.04

6. ANS:

A saturated solution is one that cannot dissolve any more solute at a specific temperature. An unsaturated solution is one that contains less solute than it can usually hold at a given temperature. A supersaturated solution is one that contains more solute than it can usually hold at a given temperature.

PTS: 1 REF: C OBJ: 7.1 STA: SS2.01

7. ANS:

(a) supersaturated

(b) unsaturated

(c) saturated

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

8. ANS:

A sodium hydroxide solution. (There are several other possibilities that students could choose by using a solubility rules table.)

PTS: 1 REF: I OBJ: 7.5 STA: SS2.04

9. ANS:

(a) $BaCl_{2(aq)} + K_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2KCl_{(aq)}$

(b) $Ba^{2+}{}_{(aq)} + \cancel{2Cl^{-}{}_{(aq)}} + \cancel{2K^{+}}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)} + \cancel{2K^{+}}{}_{(aq)} + \cancel{2Cl^{-}}{}_{(aq)}$

(c) $Ba^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

PTS: 1 REF: I OBJ: 7.3 STA: SS2.05

10. ANS:

(a) $Ni(NO_3)_{2(aq)} + Na_2SO_{3(aq)} \rightarrow NiSO_{3(s)} + 2NaNO_{3(aq)}$

(b) $Ni^{2+}{}_{(aq)} + \cancel{2NO_3{}^{-}}{}_{(aq)} + \cancel{2Na^{+}}{}_{(aq)} + SO_3{}^{2-}{}_{(aq)} \rightarrow NiSO_{3(s)} + \cancel{2Na^{+}}{}_{(aq)} + \cancel{2\ NO_3{}^{-}}{}_{(aq)}$

(c) $Ni^{2+}{}_{(aq)} + SO_3{}^{2-}{}_{(aq)} \rightarrow NiSO_{3(s)}$

PTS: 1 REF: I OBJ: 7.3 STA: SS2.05

11. ANS:

Potassium nitrate has greater solubility in water because the solubility curve for KNO_3 is much steeper than the curve for $KClO_3$.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

12. ANS:

$Pb^{2+}_{(aq)} + 2I^{-}_{(aq)} \rightarrow PbI_{2(s)}$

PTS: 1 REF: I OBJ: 7.3 STA: SS2.05

13. ANS:

$Ca(OH)_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2OH^{-}_{(aq)}$

PTS: 1 REF: C OBJ: 8.1 STA: SS2.07

14. ANS:

(a) In acidic solutions, $[H^{+}_{(aq)}] > 1 \times 10^{-7}$ mol/L

(b) In basic solutions, $[H^{+}_{(aq)}] < 1 \times 10^{-7}$ mol/L

PTS: 1 REF: K/U OBJ: 8.2 STA: SS1.07

15. ANS:

An Arrhenius acid is a substance that reacts with water to form hydronium ions. An Arrhenius base is a substance that dissociates to form hydroxide ions.

PTS: 1 REF: K/U OBJ: 8.4 STA: SS1.05

16. ANS:

A Bronsted acid is a proton donor. A Bronsted base is a proton acceptor.

PTS: 1 REF: K/U OBJ: 8.4 STA: SS1.05

17. ANS:

$HF_{(aq)}$ and $F^{-}_{(aq)}$ are conjugate acid-base pairs. $H_3O^{+}_{(aq)}$ and $H_2O_{(l)}$ are conjugate acid-base pairs.

PTS: 1 REF: K/U OBJ: 8.4 STA: SS1.05

18. ANS:

$2HClO_{4(aq)} + Ba(OH)_{2(aq)} \rightarrow Ba(ClO_4)_{2(aq)} + 2H_2O_{(l)}$

PTS: 1 REF: I OBJ: 8.5 STA: SS2.07

PROBLEM

19. ANS:

$m_{Na_3PO_4} = 150.0\ g$

$C_{Na_3PO_4} = 0.23\ mol/L$

$M_{Na_3PO_4} = 163.94\ g/mol$

$$n_{Na_3PO_4} = 150.0\ g \times \frac{1\ mol}{163.94\ g}$$
$$= 0.9150\ mol$$

$$v_{Na_3PO_4} = \frac{0.9150\ mol}{0.23\ mol/L}$$
$$= 4.0\ L$$

The volume of the solution will be 4.0 L.

PTS: 1 REF: I OBJ: 6.3 STA: SS2.02

20. ANS:

$m_{NaHSO_4} = 680\ g$

$v_{NaHSO_4} = 3.4\ L$

$$C_{\text{NaHSO}_4} = \frac{680\text{ g}}{3400\text{ mL}}$$

$$= \frac{0.20\text{ g}}{1\text{ mL}} \times 100$$

$$= \frac{20\text{ g}}{100\text{ mL}}$$

The concentration of $NaHSO_4$ is 20 g/100 mL.

PTS: 1 REF: I OBJ: 6.3 STA: SS2.02

21. ANS:

$v_i = 600\text{ mL}$

$C_i = 1.5\text{ mol/L}$

$C_f = 1.0\text{ mol/L}$

$$v_i C_i = v_f C_f$$

$$v_{f\,(\text{CaCl}_2)} = \frac{v_i C_i}{C_f}$$

$$= \frac{0.600\text{ L} \times 1.5\text{ mol/L}}{1.0\text{ mol/L}}$$

$$= 0.90\text{ L}$$

$$= 900\text{ mL}$$

$$v_f = v_i + v_{\text{H}_2\text{O (added)}}$$

$$v_{\text{H}_2\text{O (added)}} = v_f - v_i$$

$$= 900\text{ mL} - 600\text{ mL}$$

$$= 300\text{ mL}$$

The amount of water that must be added for the dilution is 300 mL.

PTS: 1 REF: I OBJ: 6.3 STA: SS2.02

22. ANS:

$$[NO_3{}^-{}_{(aq)}] = 1.55 \text{ ppm}$$
$$= 1.55 \text{ mg/L}$$

$$m_{NO_3{}^-{}_{(aq)}} = \frac{1.55 \text{ mg}}{1 \text{ L}} \times 11.0 \text{ L}$$
$$= 17.0 \text{ mg}$$

The container of mineral water contains 17.0 mg of dissolved nitrate.

PTS: 1 REF: I OBJ: 6.3 STA: SS2.02

23. ANS:

$$C_{NaClO_{(aq)}} = \frac{5.25 \text{ g}}{100 \text{ mL}} \times \frac{1 \text{ mol}}{74.44 \text{ g}} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$
$$= 0.705 \text{ mol/L}$$

The sodium hypochlorite concentration is 0.705 mol/L.

PTS: 1 REF: I OBJ: 6.3 STA: SS2.02

24. ANS:

(a) mass of KCl dissolved at 60ºC = 45 g/100mL

A saturated KCl solution has 45 g of dissolved KCl per 100 mL of water at 60ºC.

(b) solubility of a saturated solution of KCl at 30ºC

$$\frac{36 \text{ g}}{100 \text{ mL}} = \frac{x}{2500 \text{ mL}}$$
$$(100 \text{ mL})x = (36 \text{ g})(2500 \text{ mL})$$
$$x = \frac{(36 \text{ g})(2500 \text{ mL})}{100 \text{ mL}}$$
$$= 900 \text{ g}$$

The mass of KCl that can be dissolved in 2.5 L of water at 30ºC is 900 g.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

25. ANS:

solubility of $KClO_3$ at 50ºC = $\dfrac{19\ \text{g}}{100\ \text{mL}}$

solubility of $KClO_3$ at 5ºC = $\dfrac{4\ \text{g}}{100\ \text{mL}}$

mass of $KClO_3$ crystallizing = $19\ \text{g} - 4\ \text{g} = \dfrac{15\ \text{g}}{100\ \text{mL}}$

$$\frac{15\ \text{g}}{100\ \text{mL}} = \frac{m}{1000\ \text{mL}}$$

$$(14\ \text{g})(1000\ \text{mL}) = (100\ \text{mL})m$$

$$m = \frac{(14\ \text{g})(1000\ \text{mL})}{100\ \text{mL}}$$

$$= 150\ \text{g}$$

The mass of potassium chlorate that will crystallize from a 1.0-L solution is 150 g.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.03

26. ANS:

$Na_2CO_{3(aq)} + CoCl_{2(aq)} \rightarrow CoCO_{3(s)} + 2\ NaCl_{(aq)}$

250 mL v

1.5 mol/L 1.0 mol/L

$$C = \frac{n}{v}$$

$$n_{Na_2CO_3} = v \times C$$

$$= (0.250\ \text{L}) \times \frac{(1.5\ \text{mol})}{1\ \text{L}}$$

$$= 0.38\ \text{mol}$$

$$n_{CoCl_2} = 0.38 \text{ mol} \times \frac{1}{1}$$
$$= 0.38 \text{ mol}$$

$$v_{CoCl_2} = 0.38 \text{ mol} \times \frac{1 \text{ L}}{1 \text{ mol}}$$
$$= 0.38 \text{ L or } 380 \text{ mL}$$

The volume of cobalt(II) chloride required is 380 mL.

PTS: 1 REF: I OBJ: 7.6 STA: SS2.08

27. ANS:

$Na_2CO_{3(aq)}$ + $Ca(NO_3)_{2(aq)}$ → $CaCO_{3(s)}$ + $2NaNO_{3(aq)}$

100 mL	200 mL	*m*	*C*
0.20 mol/L	0.10 mol/L		

$$C = \frac{n}{v}$$

$$n_{Na_2CO_3} = v \times C = 0.100 \text{ L} \times 0.20 \text{ mol/L} = 0.020 \text{ mol}$$

$$n_{Ca(NO_3)_2} = v \times C = 0.200 \text{ L} \times 0.10 \text{ mol/L} = 0.020 \text{ mol}$$

Since one mole of Na_2CO_3 reacts completely with one mole of $Ca(NO_3)_2$ from the equation, then this mixing of solutions will be a complete reaction.

$$m_{CaCO_3} = 0.020 \text{ mol } Na_2CO_3 \times \frac{1 \text{ mol } CaCO_3}{1 \text{ mol } Na_2CO_3} \text{ x } \frac{100.09 \text{ g}}{1 \text{ mol } CaCO_3}$$
$$= 2 \text{ g}$$

The mass of calcium carbonate that precipitates is 2 g.

$$C_{NaNO_3} = \frac{2 \times 0.02 \text{ mol}}{0.100 \text{ L} + 0.200 \text{ L}}$$

$$= \frac{0.04 \text{ mol}}{0.300 \text{ L}}$$

$$= 0.1 \text{ mol/L}$$

The concentration of the sodium nitrate solution is 0.1 mol/L.

PTS: 1 REF: I OBJ: 7.6 STA: SS2.08

28. ANS:

$AgNO_{3(aq)} + KCl_{(aq)} \rightarrow AgCl_{(s)} + KNO_{3(aq)}$

3.0 L v

0.85 mol/L C

$$C = \frac{n}{v}$$

$$n_{AgNO_3} = C \times v$$

$$= \frac{0.85 \text{ mol}}{\text{L}} \times 3.0 \text{ L}$$

$$= 2.6 \text{ mol}$$

Since 1 mol of silver nitrate reacts with 1 mol of potassium chloride, then 2.6 mol of potassium chloride will be required.

$$C_{KCl} = \frac{n}{v}$$

$$= \frac{2.6 \text{ mol}}{1.0 \text{ L}}$$

$$= 2.6 \text{ mol/L}$$

An appropriate solute could be potassium chloride with a concentration of 2.6 mol/L. The student could use a 1.0-L volume of this solution.

PTS: 1 REF: I OBJ: 7.6 STA: SS2.08

29. ANS:

$3Cu_{(s)}$ + $8HNO_{3(aq)}$ → $4H_2O_{(g)}$ + $3Cu(NO_3)_{2(aq)}$ + $2NO_{(g)}$

500 g 2.5 L

m 3.0 mol/L

$$n_{HNO_3} = v \times C$$
$$= 2.5\text{ L} \times 3.0\text{ mol/L}$$
$$= 7.5\text{ mol}$$

$$n_{Cu} = 500\text{ g} \times \frac{1\text{ mol}}{63.55\text{ g}}$$
$$= 7.87\text{ mol}$$

$$n_{Cu\,(reacted)} = 7.5\text{ mol HNO}_3 \times \frac{3\text{ mol Cu}}{8\text{ mol HNO}_3}$$
$$= 2.8\text{ mol}$$

$$n_{Cu\,(unreacted)} = n_{Cu\,(have)} - n_{Cu\,(reacted)}$$
$$= 7.87\text{ mol} - 2.8\text{ mol}$$
$$= 5.07\text{ mol}$$

$$m_{Cu\,(left)} = 5.07\text{ mol} \times \frac{63.55\text{ g}}{1\text{ mol}}$$
$$= 320\text{ g}$$

The mass of copper metal left unreacted is 320 g.

PTS: 1 REF: I OBJ: 7.6 STA: SS2.08

30. ANS:

$3BaCl_{2(aq)}$ + $Fe_2(SO_4)_{3(aq)}$ → $3BaSO_{4(s)}$ + $2FeCl_{3(aq)}$

100.0 mL 100.0 mL *m*

0.100 mol/L 0.100 mol/L

$$n_{BaSO_4} = 0.100\ \text{L} \times 0.100\ \text{mol/L BaCl}_2 \times \frac{3\ \text{mol BaSO}_4}{3\ \text{mol BaCl}_2}$$

$$= 0.01\ \text{mol}$$

$$m_{BaSO_4} = 0.01\ \text{mol} \times \frac{233.39\ \text{g}}{1\ \text{mol}}$$

$$= 2.3\ \text{g}$$

The theoretical mass of barium sulphate is 2.3 g.

$$\%\ \text{yield BaSO}_4 = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

$$= \frac{2.0\ \text{g}}{2.3\ \text{g}} \times 100$$

$$= 87\%$$

The % yield of the barium sulphate precipitate was 87%.

PTS: 1 REF: I OBJ: 7.6 STA: SS2.08

31. ANS:

solubility of K_2SO_4 at 20ºC = $\frac{11\ \text{g}}{100\ \text{mL}}$

solubility of K_2SO_4 at 70ºC = $\frac{20\ \text{g}}{100\ \text{mL}}$

$$m_{K_2SO_4} = \frac{20\ \text{g} - 11\ \text{g}}{100\ \text{mL}}$$

$$= \frac{9\ \text{g}}{100\ \text{mL}}$$

$$m_{K_2SO_4} = \frac{m}{750 \text{ mL}}$$

$$\frac{9 \text{ g}}{100 \text{ mL}} = \frac{m}{750 \text{ mL}}$$

$$m = 9 \text{ g} \times \frac{750 \text{ mL}}{100 \text{ mL}}$$

$$= 68 \text{ g}$$

The extra mass of potassium sulphate that could be dissolved is 68 g.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

32. ANS:

$$m_{CO_2} = \frac{0.586 \text{ g} - 0.169 \text{ g}}{100 \text{ mL}}$$

$$= \frac{0.417 \text{ g}}{100 \text{ mL}}$$

$$m_{CO_2} = \frac{m}{355 \text{ mL}}$$

$$\frac{m}{355 \text{ mL}} = \frac{0.417 \text{ g}}{100 \text{ mL}}$$

$$m = 0.417 \text{ g} \times \frac{355 \text{ mL}}{100 \text{ mL}}$$

$$= 1.48 \text{ g}$$

The mass of carbon dioxide bubbling out of the Coke is 1.48 g.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

33. ANS:

$$BaSO_4 \text{ solubility} = \frac{0.25 \text{ mg}}{100 \text{ mL}} = \frac{s}{2000 \text{ mL}}$$

$$s = \frac{2000 \text{ mL} \times 0.25 \text{ mg}}{100 \text{ mL}}$$

$$= 5 \text{ mg}$$

$$\text{mass of BaSO}_4\text{ precipitate} = 1.5\text{ g} - 0.005\text{ g}$$
$$= 1.5\text{ g}$$

The mass of the barium sulphate precipitate is 1.5 g.

PTS: 1 REF: I OBJ: 7.1 STA: SS2.04

34. ANS:

$$m_{O_2} = \frac{14.7\text{ mg} - 8.7\text{ mg}}{1\text{ L}}$$
$$= \frac{6.0\text{ mg}}{1\text{ L}}$$

$$m_{O_2} = \frac{6.0\text{ mg}}{1\text{ L}} = \frac{m}{75\text{ L}}$$
$$m = 6.0\text{ mg/L} \times 75\text{ L}$$
$$= 450\text{ mg}$$

The difference in the mass of oxygen dissolved at the two temperatures is 450 mg.

PTS: 1 REF: MC OBJ: 7.1 STA: SS3.02

35. ANS:

$$[H^+_{(aq)}] = 10^{-pH}$$
$$= 10^{-7.5}\text{ mol/L}$$
$$= 3.2 \times 10^{-8}\text{ mol/L}$$

The hydrogen ion concentration of the swimming pool is 3.2×10^{-8} mol/L.

PTS: 1 REF: K/U OBJ: 8.2 STA: SS1.07

36. ANS:

$2HCl_{(aq)} + Na_2CO_{3(aq)} \rightarrow H_2CO_{3(aq)} + 2NaCl_{(aq)}$

15.0 mL 10.00 mL

C 0.250 mol/L

$$C_{HCl} = 10.00\ mL\ Na_2CO_3 \times \frac{0.250\ mol\ Na_2CO_3}{1\ L\ Na_2CO_3} \times \frac{2\ mol\ HCl}{1\ mol\ Na_2CO_3} \times \frac{1}{15.0\ mL}$$

$$= 0.333\ mol/L$$

Since the sample of HCl had been diluted by a factor of 10, the original concentration of the HCl must be 10 times greater.

The original concentration was 3.33 mol/L.

PTS: 1 REF: I OBJ: 8.5 STA: SS2.09

37. ANS:

$HF_{(aq)} + KOH_{(aq)} \rightarrow KF_{(aq)} + H_2O_{(l)}$

85.0L *m*

6.0 mol/L 56.11 g/mol

$$n_{HF} = 85.0\ L \times 6.0\ mol/L$$
$$= 510\ mol$$

$$n_{KOH} = 510\ mol \times \frac{1}{1}$$
$$= 510\ mol$$

$$m_{KOH} = 510\ mol \times \frac{56.11\ g}{1\ mol}$$
$$= 28\,614\ g$$
$$= 29\ kg$$

A 29 kg mass of potassium hydroxide pellets would neutralize the acid.

PTS: 1 REF: I OBJ: 8.5 STA: SS2.08

38. ANS:

$Mg(OH)_{2(aq)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$

12.0 mg 0.01 mol/L

58.31 g/mol *v*

$$n_{Mg(OH)_2} = 0.012\ g \times \frac{1\ mol}{58.32\ g}$$

$$= 0.000206\ mol$$

$$n_{HCl} = 0.000206\ mol \times \frac{2}{1}$$

$$= 0.000412\ mol$$

$$v_{HCl} = 0.000412\ mol \times \frac{1\ L}{0.01\ mol}$$

$$= 0.04\ L$$

$$= 40\ mL$$

The milk of magnesia can neutralize 40 mL of stomach acid.

PTS: 1 REF: I OBJ: 8.5 STA: SS2.09