Solubility & Equilibrium Unit Review

This review is worth 3 marks of your total test marks. It must be completed on test day. 3 marks will be given to students who have fully completed this review with all work shown. Partial marks will be given for incomplete questions.

How to study: Calculation type questions: Practice Practice and Practice – Attempt all the questions in this review and mark down questions you have problems with.

Conceptual Questions: Ask yourself, what exactly is this concept about? How does it relate to each other? This unit contains a lot of concepts that are related to each other, try to link them!

1. Determine the **ions that form** when each solid compound dissolves in water. Be sure to indicate the state of matter each product is in.
   a) $NaCl_{(s)} \rightarrow$
   b) $Ag_2CrO_{4\,(s)} \rightarrow$
   c) $SrCO_{3\,(s)} \rightarrow$
   d) $Fe(OH)_{2\,(s)} \rightarrow$
   e) $Zn(CH_3COO)_{2\,(s)} \rightarrow$
2. Determine what **PRODUCTS are formed** by mixing the following aqueous solutions together. Be sure to indicate what state of matter each product is in.
   a) $AgNO_{3\,(aq)} + NaCH_3COO_{(aq)} \rightarrow$ _____ + _____
   b) $NaCl_{(aq)} + Pb(NO_3)_{2\,(aq)} \rightarrow$ _____ + _____
   c) $Mg(OH)_{2\,(aq)} + AlCl_{3\,(aq)} \rightarrow$ _____ + _____
   d) $CaBr_{2\,(aq)} + CuCl_{(aq)} \rightarrow$ _____ + _____
3. Write the **Balanced Molecular Equation**, the **Complete Ionic Equation** and the **Net Ionic Equation** for the following Precipitation Reactions.
   a) Barium Hydroxide + Iron (III) Nitrate
   b) Strontium Hydroxide + Calcium Iodide

Qualitative Analysis

4. A solution contains one or more of Ag^+, Ba^{2+} and Ni^{2+}. What ions could be added, and in what order, to determine which of these cations are present?
   Setup a table of solubilities:

5. A solution contains Sr^{2+}, Ca^{2+} and Ag^+. What compounds could be added, and in what order, to separate these ions?
   Setup a table of solubilities:

6. A solution contains Fe^{3+}, Ca^{2+}, Ag^+ and Be^{2+}. What compounds could be added, and in what order, to separate these ions?
   Setup a table of solubilities:

Equilibrium Section:

1. What are the conditions that must be present in order to establish chemical equilibrium of a system?

2. Explain what the term dynamic equilibrium means. Provide an analogy or example.

3. Explain what the terms "stress" and "shift" mean in relation to Le Chatelier's Principle.

4. State the direction of the equilibrium shift in these reactions when the pressure is decreased.
   a) $PCl_3\ (g) + Cl_2\ (g) \rightleftharpoons PCl_5\ (g)$ shifts:_____
   b) $2\ NO\ (g) \rightleftharpoons N_2\ (g) + O_2\ (g)$ shifts:_____
   c) $4\ NH_3\ (g) + 5\ O_2\ (g) \rightleftharpoons 4\ NO\ (g) + 6\ H_2O\ (g)$ shifts:_____

5. Explain how a catalyst will affect the equilibrium concentrations and the time it takes to reach equilibrium for the reaction below:

$$N_2\ (g) + 2\ O_2\ (g) \rightleftharpoons 2\ NO_2\ (g)$$

6. Using the data below create an equilibrium graph. Make sure to label all axis and results. You will have 2 lines on this graph, one for [A] and one for [B].
   Assume that the simple reaction A ⇌ B initially has the following concentrations:
   [A] = 1.20 M and [B] = 0.00 M
   If you let the reaction take place for 18 minutes, the following results are produced:

Time (min)	Concentration A (M)	Concentration B (M)
0	**1.20**	**0.00**
1	0.60	0.60
2	0.36	0.84

4	0.22	0.97
6	0.20	1.0
8	0.20	1.0
10	0.20	1.0
11	**0.20**	**1.60**
12	0.26	1.54
14	0.29	1.51
16	0.30	1.50
18	0.30	1.50

a) Between 0 to 10 minutes, **when equilibrium finally occurs?**
b) What happens to [B] at 11 minutes?
c) According to Le Chatelier's principle, what is the stress at 11minutes and what is the shift? Was the data consistent with the theory of Le Chatelier's Principle? Why or why not?

7. Write the equilibrium expression or mass action expression (Keq) for each of the following reactions
   a. $2\ PCl_3\ (g) + O_2\ (g) \rightleftharpoons 2\ POCl_3\ (g)$
   b. $2\ SO_3\ (g) \rightleftharpoons 2\ SO_2\ (g) + O_2\ (g)$
   c. $N_2H_4\ (g) + 2\ O_2\ (g) \rightleftharpoons 2\ NO\ (g) + 2\ H_2O\ (g)$
   d. $N_2H_4\ (g) + 6\ H_2O_2\ (g) \rightleftharpoons 2\ NO_2\ (g) + 8\ H_2O\ (g)$

8. Given the following reactions and their equilibrium constants arrange them (A, B, C) in order of increasing tendency to go towards product production.
   a. $2\ CH_4\ (g) \rightleftharpoons C_2H_6\ (g) + H_2\ (g)$ Keq = 9.5×10^{-13}
   b. $CH_3OH\ (g) + H_2\ (g) \rightleftharpoons CH_4\ (g) + H_2O\ (g)$ Keq = 3.6×10^{20}
   c. $C_2H_2\ (g) + H_2O\ (g) \rightleftharpoons C_2H_5OH\ (g)$ Keq = 8.2×10^{3}

   New Order: _____

9. The colour in the following equilibrium system darkens when $FeCl_3$ is added:

   $$Fe^{3+}\ (aq) + SCN^-\ (aq) \rightleftharpoons FeSCN^{2+}\ (aq)$$

   Explain how the presence of iron (III) chloride affects the equilibrium of this system?
   (Note: $FeSCN^{2+}$ is reddish brown and Fe^{3+} / SCN^- is a light reddish orange)

10. The following reaction represents an equilibrium system:

    $$PCl_5\ (g) \rightleftharpoons PCl_3\ (g) + Cl_2\ (g)$$

    Calculate the Keq for this reaction if the concentrations at equilibrium are:
    $[PCl_5] = 0.32$ M $[PCl_3] = 0.40$ M $[Cl_2] = 0.40$ M

11. The above reaction reaches equilibrium at 25° C and has an equilibrium constant of 1.78. If the equilibrium concentrations of PCl_3 and Cl_2 are both 0.85 mol/L, calculate the concentration of PCl_5 at equilibrium.

12. In the reaction: N_2 (g) + 3 H_2 (g) ⇌ 2 NH_3 (g) the equilibrium concentration N_2 = 0.50 M and H_2 = 0.20 M. What is the equilibrium concentration of NH_3 if Keq = 122.5?

13. **Initially**, 0.0400 moles of SO_2Cl_2 (g) are placed in a 200 mL container and heated. At equilibrium, 0.0140 moles of Cl_2 (g) are present along with an unknown amount of SO_2 .
    a. Write the equilibrium **equation** for this system.

    b. Calculate the **molarity** (concentration) of each substance **<u>at equilibrium.</u>**

    c. Indicate which reaction is **favoured.**

14. **At equilibrium** there are 0.20 moles of O_2 and 1.50 moles of SO_2 in a 10.0 L vessel. What is the [SO_3] if Keq is equal to 5.0?

$$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3(g)$$

15. Initially, 0.800 mol/L of both CO and H_2 are allowed to react slowly. When equilibrium occurs there are 0.0600 mol/L of CH_4 (g) and H_2O in this reaction:

$$CO\ (g) + 3\ H_2\ (g) \rightleftharpoons CH_4\ (g) + H_2O\ (g)$$

    What is the equilibrium constant?

16. In this reaction: 4 NH_3 (g) + 3 O_2 (g) ⇌ 2 N_2 (g) + 6 H_2O (g), initially 0.500 moles of EACH reactant are placed in a 20.0 L flask. At equilibrium, [N_2] = 0.00500 M.
    a. What is the molarity of the other substances at equilibrium?
    b. What is the Keq?

17. In this reaction: $COCl_2$ (g) ⇌ CO (g) + Cl_2 (g), 0.0200 moles of $COCl_2$ dissociate (breaks down) in a 400.0 mL container at the beginning. What is the concentration of each substance at equilibrium if the Keq = 12.0?

18. A 1.0 L vessel contains the initial amount of 0.750 mol of carbon monoxide gas and 0.275 mol of steam. After 1 hour, equilibrium is reached according to this equation:

$$CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$$

    Analysis shows 0.250 mol of carbon dioxide present at equilibrium. What is the Keq for this reaction?

19. For this reaction: 2 SO_3 (g) ⇌ 2 SO_2 (g) + O_2 (g) ; Keq = 0.2, a certain amount of SO_3 was initially placed in a 2.0 L flask
    At equilibrium, the flask contained 0.30 mol of O_2 gas. What was the **original** concentration of **SO_3** gas that was placed in the flask at the start?

20. Explain using le Chatelier's principle how feeding chickens carbonated water helps to strengthen their eggshells.

$$3\ H_2O_{(l)} + 3\ CO_{2(g)} + 3\ Ca^{2+}_{(aq)} \rightleftharpoons 6\ H^{+}_{(aq)} + 3\ CaCO_{3(s)}$$

(eggshell)

21. For the reaction

$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3\ (g)$ Keq = 16

Initially, $[SO_2]$ = 5.0 mol/L, $[O_2]$ =7.9 mol/L. Calculate the reaction quotient. Is the system at equilibrium? If not, which substances are increasing and which are decreasing?

22. How many grams of $BaCrO_4$ are present in 10.0 L of a saturated solution of $BaCrO_4$?
Ksp = 1.2×10^{-10} This is a 3 step question – Hint – Find concentration, then moles, then grams.

23. Write the dissociation equation and the solubility product expression for the following, and then calculate their solubility in mol/L.
    a. CuS Ksp = 6.0×10^{-37}
    b. Ag_2CO_3 Ksp = 8.5×10^{-12}

24. The K_{sp} of CaF_2 at 25°C is 1.7×10^{-10}. If 0.75 g of CaF_2 are dissolved in 25.0 L of hot water then cooled to 25°C, will a precipitate form? Assume no volume change. Compare Qsp to Ksp.

25. The Ksp of lead (II) chloride, $PbCl_2$, is 1.6×10^{-5} . What is the solubility of lead (II) chloride in a 0.10 mol/L solution of magnesium chloride, $MgCl_2$?

Common Ion:

26. Calculate the molar solubility of ZnS in a 0.015 M solution of ZnCl2. Ksp of ZnS is 2.0×10^{-25}

27. The molar solubility of a generic substance, $M(OH)_2$ in 0.10 M KOH solution is 1.0×10^{-5} mol/L. What is the K_{sp} for $M(OH)_2$?