SCH4U Exam Review

Unit 1 – Energy Changes and Rates of Reactions

1. The molar heat of vapourization of acetone, C_3H_6O is 30.3 kJ/mol at its boiling point. How much heat would be liberated by the condensation of 1.00 g of acetone? **ANS:** 0.522 kJ

2. Aluminum reacts readily with chlorine gas to produce $AlCl_3$. What is the enthalpy change when 1.0kg of Al reacts with excess Cl_2?
   $2Al + 3Cl_2 \rightarrow 2AlCl_3 + 1408kJ$ **ANS:** 2.6×10^4 kJ

3. If the enthalpy of a system increases by 100 kJ, what must be true about the enthalpy of the surroundings? Explain.

4. What is the sign of ΔH for an exothermic change? ____ endothermic change? ____

5. A bucket of 5.45 kg of water underwent a drop in temperature from 60.30°C to 57.60°C. How much energy in kilojoules left the water? (c = 4.184 J/g°C) **ANS:** 61.6 kJ

6. Use Hess' Law to calculate the molar enthalpy for the reaction below.
   $2Ag_{(s)} + Zn(NO_3)_{2\,(aq)} \leftrightarrow Zn_{(s)} + 2AgNO_{3\,(aq)}$
   The following thermochemical equations can be used:
   $Cu(NO_3)_{2\,(aq)} + Zn_{(s)} \rightarrow Zn(NO_3)_{2\,(aq)} + Cu_{(s)}$ ΔH = -61.7 kJ
   $2AgNO_{3\,(aq)} + Cu_{(s)} \rightarrow Cu(NO_3)_{2\,(aq)} + 2Ag_{(s)}$ ΔH = -25.3 kJ **ANS:** +87.0 kJ

7. Calculate ΔH for the following reaction, which describes the preparation of an unstable acid, HNO_2, nitrous acid. $HCl_{(g)} + NaNO_{2\,(s)} \rightarrow HNO_{2\,(l)} + NaCl_{(s)}$
   Use the following thermochemical equations: **ANS:** ΔH = -78.6 kJ
   $2NaCl_{(s)} + H_2O_{(l)} \rightarrow 2HCl_{(g)} + Na_2O_{(s)}$ ΔH = +507.31 kJ
   $NO_{(g)} + NO_{2\,(g)} + Na_2O_{(s)} \rightarrow 2NaNO_{2\,(s)}$ ΔH = -427.14 kJ
   $NO_{(g)} + NO_{2\,(g)} \rightarrow N_2O_{(g)} + O_{2\,(g)}$ ΔH = -42.68 kJ
   $2HNO_{2\,(l)} \rightarrow N_2O_{(g)} + O_{2\,(g)} + H_2O_{(l)}$ ΔH = +34.35 kJ

8. Which of the following equations has a ΔH that would properly be labelled as a ΔH_f?
   (a) $CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)}$
   (b) $Ca_{(s)} + \frac{1}{2}O_{2\,(g)} \rightarrow CaO_{(s)}$
   (c) $2Fe_{(s)} + O_{2\,(g)} \rightarrow 2FeO_{(s)}$
   (d) $SO_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \rightarrow SO_{3\,(g)}$ **ANS:** (b) and (c)

9. Use the standard enthalpies of formation (ΔH_f) table to calculate ΔH for the following reactions:
   (a) $CaO_{(s)} + CO_{2\,(g)} \rightarrow CaCO_{3\,(s)}$ **ANS:** ΔH = -178.61 kJ
   (b) $C_2H_{2\,(g)} + 2H_{2\,(g)} \rightarrow C_2H_{6\,(g)}$ ΔH = -311.42 kJ
   (c) $3CaO_{(s)} + 2Fe_{(s)} \rightarrow 3Ca_{(s)} + Fe_2O_{3\,(s)}$ ΔH = +1084 kJ
   (d) $Ca(OH)_{2\,(s)} \rightarrow CaO_{(s)} + H_2O_{(l)}$ ΔH = +65.2 kJ
   (e) $2NaCl_{(s)} + H_2SO_{4\,(l)} \rightarrow Na_2SO_{4\,(s)} + 2HCl_{(g)}$ ΔH = +64.2 kJ

10. Nitrogen dioxide, an air pollutant, combines with water to make nitric acid (HNO_3), a corrosive acid, and nitrogen monoxide (NO). What is ΔH for this reaction? **ANS:** -71.5 kJ

11. State 5 factors that affect the rates of chemical reactions.

12. In the reaction $N_2 + 3I_2 \rightarrow 2NI_3$, the rate of disappearance of iodine is $2.4x10^{-3}$ mol/L·s
    (a) What is the rate of disappearance of nitrogen? **ANS:** $8.0x10^{-4}$ mol/L·s
    (b) What is the rate of appearance of NI_3? $1.6x10^{-3}$ mol/L·s

13. The rate law for the reaction $2NO + O_2 \rightarrow 2NO_2$ is rate = $k[NO]^2[O_2]$. At 25°C, $k = 7.1x10^9$ $mol^{-2}sec^{-1}$. What is the rate of reaction when [NO] = 0.0010 mol/L, $[O_2]$ = 0.034 mol/L?
    ANS: $2.4x10^2$

14. The rate law for the reaction: $2HCrO_4^{2-} + 3HSO_3^- + 5H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + 5H_2O$ is
    Rate = $k[HCrO_4^{2-}][HSO_3^-]^2[H^+]$
    (a) What is the order of the reaction with respect to each reactant? **ANS:** 1, 2, 1
    (b) What is the overall order of the reaction? **ANS:** 4

15. Draw a potential energy diagram for an endothermic & an exothermic reaction. Indicate on the diagram the activation energy for both the forward & reverse reactions and the heat of reaction (ΔH).

16. What is the rate law for the following reaction (include the rate constant value)
    $2ClO_2 + 2OH^- \rightarrow ClO_3^- + ClO_2^- + H_2O$

Experiment	Initial $[ClO_2]$ (mol/L)	Initial $[OH^-]$ (mol/L)	Initial Rate (mol/L·s)
1	0.0150	0.0250	$1.30x10^{-3}$
2	0.0150	0.0500	$2.60x10^{-3}$
3	0.0450	0.0250	$1.17x10^{-2}$

ANS: Rate = $231[ClO_2]^2[OH^-]$

Unit 2 – Chemical Systems and Equilibrium

1. How will the following equilibrium be affected by:
   heat + $CH_{4\,(g)} + 2H_2S_{(g)} \leftrightarrow CS_{2\,(g)} + 4H_{2\,(g)}$
   (a) the addition of $CH_{4\,(g)}$ **ANS:** shift right
   (b) the addition of $H_{2\,(g)}$ shift left
   (c) the removal of $CS_{2\,(g)}$ shift right
   (d) a decrease in the volume of the container shift left
   (e) an increase in temperature shift right

2. The reaction $CO_{(g)} + 2H_{2\,(g)} \leftrightarrow CH_3OH_{(g)}$ has ΔH = -18 kJ. How will the amount of CH_3OH present at equilibrium be affected by the following?
   (a) adding $CO_{(g)}$ **ANS:** increase
   (b) removing $H_{2\,(g)}$ decrease
   (c) decreasing the volume of the container increase
   (d) adding a catalyst no change
   (e) increasing the temperature decrease

3. At 773°C, a mixture of $CO_{(g)}$, $H_{2\,(g)}$ and $CH_3OH_{(g)}$ was allowed to come to equilibrium. The following equilibrium concentrations were then measured: [CO] = 0.105 M, $[H_2]$ = 0.250 M, and $[CH_3OH]$ = 0.00261 M. Calculate k_{eq} for the reaction $CO_{(g)} + 2H_{2\,(g)} \leftrightarrow CH_3OH_{(g)}$. **ANS:** 0.398

4. At a certain temperature, K_{eq} = 0.18 for the equilibrium $PCl_{3\,(g)} + Cl_{2\,(g)} \leftrightarrow PCl_{5\,(g)}$
   Suppose a reaction vessel contained these three gases at the following concentrations:
   $[PCl_3]$ = 0.0520 M, $[Cl_2]$ = 0.0140 M, $[PCl_5]$ = 0.00600 M.
   Is the system in the state of equilibrium? If not which direction will the reaction have to proceed to reach equilibrium? **ANS:** k=8.242, shifts left

5. k = 64 for the reaction, $N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrow 2NH_{3\,(g)}$, at a certain temperature. Suppose it was found that an equilibrium mixture of these gases contained 0.280 M NH_3 and 0.00840 M N_2. What was the concentration of H_2 in the mixture? **ANS:** 0.53

6. At high temperature, 0.500 mol of HBr was placed in a 1.00 L container and allowed to decompose according to the reaction $2HBr_{(g)} \leftrightarrow H_{2\,(g)} + Br_{2\,(g)}$. At equilibrium the concentration of Br_2 was measured to be 0.130 M. What is the k_{eq} for this reaction at this temperature? **ANS:** 0.293

7. A 0.100 mol sample of formaldehyde vapour, CH_2O, was placed in a heated 1.00 L vessel and some of it decomposed. The reaction is: $CH_2O_{(g)} \leftrightarrow H_{2\,(g)} + CO_{(g)}$
At equilibrium, the $CH_2O_{(g)}$ concentration was 0.080 mol/L. Calculate K_{eq}. **ANS:** 5.0×10^{-3}

8. The equilibrium constant for the reaction: $SO_{3\,(g)} + NO_{(g)} \leftrightarrow NO_{2\,(g)} + SO_{2\,(g)}$ was found to be 0.500 at a certain temperature. If 0.300 mol of SO_3 and 0.300 mol of NO were placed in a 2.00 L container and allowed to react, what would be the equilibrium concentration of each gas?
ANS: 0.0621 M, 0.088 M

9. At a certain temperature the reaction: $CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2\,(g)} + H_{2\,(g)}$ has K = 0.400.
Exactly 1.00 mol of each gas was placed into a 100 L vessel and the mixture was allowed to react. What was the equilibrium concentration of each gas? **ANS:** 7.8×10^{-3}, 0.0123

10. When 14 g of $CO_{(g)}$ and 9 g of $H_2O_{(g)}$ are placed in a 5.0 L container, the following reaction occurs:
$CO_{(g)} + H_2O_{(g)} \leftrightarrow H_{2\,(g)} + CO_{2\,(g)}$
At equilibrium there are 16.33g of CO_2. What is the value of the equilibrium constant? **ANS:** 8.3

11. The reaction $H_{2\,(g)} + Br_{2\,(g)} \leftrightarrow 2HBr_{(g)}$ has an equilibrium constant of 2.0×10^{-9} at 25°C. If 0.100 mol of H_2 and 0.100 mol of Br_2 were placed in a 10.0 L container and allowed to react, what would all the equilibrium concentrations be at 25°C? **ANS:** 4.47×10^{-7}, 1.0×10^{-2}

12. Assuming 100% ionization of HCl in dilute solutions, what is the pH of 0.010 M HCl? **ANS:** 2

13. A sodium hydroxide solution is prepared by dissolving 6.0 g NaOH in 1.00 L of solution. Assuming that 100% dissociation occurs, what is the pOH and pH of this solution? **ANS:** 0.82, 13.18

14. A solution was made by dissolving 0.837 g $Ba(OH)_2$ in 100 mL final volume. If $Ba(OH)_2$ is fully broken up into its ions, what is the pOH and the pH of the solution? **ANS:** 1.01, 12.99

15. A soft drink was put on the market with $[H^+] = 1.4 \times 10^{-5}$ mol/L. What is its pH? **ANS:** 4.85

16. Write equations for the dissociation of the following ionic compounds in water.
(a) LiCl (b) $BaCl_2$ (c) $Al(C_2H_3O_2)_3$ (d) $(NH_4)_2CO_3$ (e) $FeCl_3$

17. Calculate the number of moles of each of the ions in the following solutions.
(a) 25.0 mL of 1.30 M KOH **ANS:** 0.0325
(b) 37.5 mL of 0.50 M $CaCl_2$ 0.019, 0.038
(c) 35.0 mL of 0.40 M $Al_2(SO_4)_3$ 2.8×10^{-2}, 4.2×10^{-2}

18. Calculate the pH of a 0.100M CH_3COOH ($k_a = 1.8 \times 10^{-5}$) **ANS:** 2.87

19. Calculate the pH of 0.20 M methylamine, CH_3NH_2. ($k_b = 3.6 \times 10^{-4}$) **ANS:** 11.9

20. Periodic acid, HIO_4, is an important oxidizing agent and moderately strong acid. In a 0.10 M solution of HIO_4, the $[H_3O^+] = 3.8x10^{-2}$ M. Calculate the k_a for periodic acid. **ANS:** 0.023

21. Calculate the k_b for a 0.12 M solution of hydrazine, NH_2NH_2 with a pH of 10.65. **ANS:** $1.7x10^{-6}$

22. Calculate the k_a for a 0.15 M solution of benzoic acid, C_6H_5COOH with a pH of 2.51. **ANS:** $6.4x10^{-5}$

23. When butter turns rancid, the foul odour is mostly that of butanoic acid (butyric acid), a weak acid. Calculate the k_a of a 0.001 M butanoic acid (HBu) solution that has a pH of 3.40. **ANS:** $2.63x10^{-4}$

24. Calculate the values of $[OH^-]$, pOH and pH in a 0.20 M ammonia (NH_3) solution.
$NH_3 + H_2O \Leftrightarrow NH_4^+ + OH^-$ $k_b = 1.8x10^{-5}$ **ANS:** $1.9x10^{-3}$, 2.72, 11.28

25. How many millilitres of 0.200 M NaOH are needed to completely neutralize 15.0 mL of 0.300 M H_3PO_4? **ANS:** 67.5 mL

26. In a titration, 24.00 mL of 0.100 M NaOH was needed to react with 20.00 mL of HCl solution. What is the molarity of the acid? **ANS:** 0.12 M

27. Write the k_{sp} expression for these compounds: (a) CaF_2 (b) $PbSO_4$ (c) $Fe(OH)_3$

28. Copper(I) chloride has $k_{sp} = 1.9x10^{-7}$. Calculate the molar solubility of CuCl in (a) pure water (b) 0.010 M HCl solution (c) 0.10 M HCl solution (d) 0.10 M $CaCl_2$ solution.
ANS: $4.4x10^{-4}$, $1.9x10^{-5}$, $1.9x10^{-6}$, $9.5x10^{-7}$

29. What is the common ion effect? How does Le Chatelier's principle explain it?

30. Barium sulphate, $BaSO_4$, is so insoluble that is can be swallowed without significant danger, even though Ba^{2+} is toxic. At 25°C, 1.00 L of water dissolves only 0.00245 g of $BaSO_4$.
(a) How many moles of $BaSO_4$ dissolve per liter?
(b) What are the molar concentrations of Ba^{2+} and SO_4^{2-} in a saturated $BaSO_4$ solution?
(c) Calculate k_{sp} for $BaSO_4$. **ANS:** (a) $1.05x10^{-5}$ (b) $1.05x10^{-5}$ (c) $1.10x10^{-10}$

31. Calcium sulphate is found in plaster. At 25°C the value of k_{sp} for $CaSO_4$ is $2.4x10^{-5}$. What is the calculated solubility of $CaSO_4$ in water expressed in moles per liter? **ANS:** $4.9x10^{-3}$

32. Chalk is $CaCO_3$ and at 25°C its $K_{sp} = 4.5x10^{-9}$. What is the molar solubility of $CaCO_3$? How many grams of $CaCO_3$ dissolve in 100 mL of water? **ANS:** $6.7x10^{-5}$, $6.7x10^{-4}$

33. Calculate the molar solubility of lead(II) iodide, PbI_2, in water ($k_{sp} = 7.9x10^{-9}$) **ANS:** $1.25x10^{-3}$

34. What is the molar solubility of Ag_2CO_3 in water (the solubility product constant is $8.1x10^{-12}$)
ANS: $1.3x10^{-4}$

Unit 3 – Electrochemistry

1. In the reaction $H_2 + Cl_2 \rightarrow 2HCl$, which substance is the oxidizing agent and which is the reducing agent? Which substance is oxidized and which is reduced? **ANS:** H_2 = RA, Cl_2 = OA

2. Assign oxidation numbers to the atoms indicated by boldface type.
(a) $\mathbf{S}^{2-}$ (b) $\mathbf{S}O_2$ (c) $\mathbf{P}_4$ (d) $\mathbf{P}H_3$ **ANS:** -2, +4, 0, -3

3. Assign oxidation numbers to the atoms indicated by boldface type.
   (a) **Cl**O_4^{1-} (b) **Cr**Cl_3 (c) **Sn**S_2 (d) **Au**$(NO_3)_3$ **ANS:** +7, +3, +4, +3

4. Assign oxidation numbers to the atoms indicated by boldface type.
   (a) Na_2H**P**O_4 (b) Na_2**S**$_4O_6$ (c) **Cl**F_3 (d) **N**O^{1+} (e) **Cr**$_2O_7^{2-}$ (f) **S**O_3^{2-}
   ANS: +5, +2.5, +3, +3, +6, +4

5. Balance these equations using oxidation numbers. Identify the oxidizing and reducing agent in each.
   (a) $CuO + NH_3 \mid Cu + N_2$ (neutral) **ANS:** 3:2 ⏐3:3:1
   (b) $ClO_3^- + SO_2 \mid SO_4^{2-} + Cl^-$ (acidic) 3:1:3 ⏐3:6:1

6. Use the half-cell reaction method to write equations for these reactions.
   (a) $NO_3^- + Bi \mid Bi^{3+} + NO_2$ (acidic) **ANS:** 6:3:1 ⏐1:3:3
   (b) $Cr_2O_7^{2-} + I^- \mid Cr^{3+} + I_2$ (acidic) 14:1:6 ⏐2:3:7
   (c) $Cr^{3+} + ClO_3^- \mid ClO_2 + Cr_2O_7^{2-}$ (acidic) 1:2:6 ⏐6:1:2
   (d) $MnO_4^- + NO_2^- \mid MnO_2 + NO_3^-$ (basic) 1:2:3 ⏐2:3:2
   (e) $ClO^- \mid Cl^- + ClO_3^-$ (basic) 3 ⏐2:1

7. Determine which of the following reactions should occur spontaneously.
   (a) $Br_2 + 2Cl^- \mid Cl_2 + 2Br^-$ **ANS:** E° = -0.3 V; no
   (b) $Ni^{2+} + Fe \mid Fe^{2+} + Ni$ E° = +0.18; yes

8. Calculate the standard cell potential for the following reactions:
   (a) $NO_3^- + 4H^+ + 3Fe^{2+} \mid 3Fe^{3+}\ NO + 2H_2O$ **ANS:** E° = 0.19 V
   (b) $Ca^{2+} + Fe \mid Ca + Fe^{2+}$ E° = -2.35 V

9. From the half-reactions below, determine the cell reaction and standard cell potential.
   $BrO_3^- + 6H^+ + 6e^- \mid Br^- + 3H_2O$ E° = +1.44 V
   $I_2 + 2e^- \mid 2I^-$ E° = +0.54 V ANS: E° = 0.90 V

10. What is the standard cell potential & the overall reaction in the following galvanic cell:
    $MnO_2 + 4H^+ + 2e^- \mid Mn^{2+} + 2H_2O$ E° = +1.23 V
    $PbCl_2 + 2e^- \mid Pb + 2Cl^-$ E° = -0.27 V **ANS:** E° = 1.50 V

Unit 4 – Structure and Properties

1. Draw Lewis Structures and predict the shape of the following:

   (a) $SiCl_4$ (b) BH_3 (c) SCl_2 **ANS:** tetrahedral, trigonal planar, bent
   (d) CS_2 (e) CN^- (f) SeO_3 linear, linear, trigonal planar
   (g) SeO_2 (h) NO_2^- (i) $SbCl_6^-$ bent, bent, octahedral
   (j) IO_3^- (k) TeF_4 (l) ClF_5 pyramidal, seesaw, square pyramidal
   (m) XeF_4 (n) ClO_4^- (o) AsH_3 square planar, tetrahedral, pyramidal

2. What are the bond angles for the following VSEPR shapes:
   (a) bent (b) trigonal planar (c) tetrahedral (d) trigonal pyramidal (e) linear
   ANS: 104.5, 120, 109.5, 107, 180

3. What condition must be met if a molecule having polar bonds is to be nonpolar?

4. Use a drawing to show why the SO_2 molecule is polar.

5. Which of the following molecules would be polar: (a) $SnCl_4$ (b) $AsCl_3$ (c) H_2Se (d) PBr_3 (e) $SbCl_5$ (f) SO_3 **ANS:** (b), (c), (d)

6. Describe the trend in boiling points using reference to Intermolecular Forces.

Unit 5 – Organic Chemistry

1. Write the IUPAC names for the following hydrocarbons:

	ANS
(a) $CH_3CH_2CH_2CH_2CH_2CH_3$	a) hexane
(b) $CH_3CH_2CH_2CH(CH_3)CH_3$	b) 2-methylpentane
(c) $CH_3CH(CH_3)CH_2CH(CH_3)CH_2CH_3$	c) 2,4-dimethylhexane
(d) $CH_3CH_2CH(CH_3)CH_2CH(CH_3)CH_3$	d) 2,4-dimethylhexane
(e) $CH_3CH_2CH{=}CHCH_2CH_3$	e) hex-3-ene
(f) $CH_3CH(CH_3)CH{=}CHCH_3$	f) 4-methylpent-2-ene

2. Draw structural formulas for the following:
   a) 2,2-dimethyloctane
   b) 1,1-diethylcyclohexane
   c) 1,3-dimethylcyclopentane
   d) 6-ethyl-7-methyl-5-isopropyloct-1-ene
   e) ortho-dimethylbenzene
   f) meta-dimethylbenzene

3. Draw and name the product(s) for the following reactions.
   b) propanoic acid + methanamine (condensation)
   c) 2-pentanol (elimination)
   d) benzene + Cl_2 (substitution)
   e) cyclopropene + HCl (addition)
   f) propanoic acid + methanol (esterification)
   g) ethyl methanoate (hydrolysis)
   h) bromoethane (elimination)
   i) butanal (oxidation)
   j) butanone (reduction)

4. Textbook: pg. p74 #25, 36