



## PHYSICAL CHEMISTRY EXAM, questions and answers

Physical Chemistry (Cape Peninsula University of Technology)

Subject	PHYSICAL CHEMISTRY 2	Code	PCH200S/PCH201S/ PCH22SX/PCH21SX
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Pages	9	Date	15 NOVEMBER 2013
Annexures	2	Time	09:00 - 12:00

Course	NATIONAL DIPLOMA: ANALYTICAL CHEMISTRY NATIONAL DIPLOMA: CHEMICAL ENGINEERING
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Instructions
<ol style="list-style-type: none"> <li>1. ANSWER ALL THE QUESTIONS</li> <li>2. FULL MARKS : 100</li> <li>3. MARKS AVAILABLE :100</li> </ol>
Requirements
<p>Calculators may be used One yellow data sheet</p>

**DO NOT turn the page over before the starting time**

**Section A**

Answer the following questions on the loose answer sheet provided by drawing a cross in the space provided for the correct answer.

- A 25.0 mL sample of 0.150 M hypochlorous acid is titrated with a 0.150 M NaOH solution. What is the pH after 26.0 mL of base is added? The  $K_a$  of hypochlorous acid is  $3 \times 10^{-8}$

  - 2.54
  - 7.00
  - 7.51
  - 7.54
  - 11.47
- A certain chemical reaction has an equilibrium constant of  $1 \times 10^{-8}$ . What does this say about the progress of the reaction?

  - There is significant reaction but it does not go to completion.
  - There is very little reaction.
  - The reaction is essentially complete.
  - The reactants do not react at all.
  - There are only products at equilibrium.
- A mixture is prepared with the following concentrations in  $\text{molL}^{-1}$ :  
[CO] = 0.035, [Cl<sub>2</sub>] = 0.015, [COCl<sub>2</sub>] = 0.95  
The equilibrium constant for the reaction

$$\text{CO (g) + Cl}_2 \text{ (g)} \rightleftharpoons \text{COCl}_2 \text{ (g)}$$

is  $1.2 \times 10^{-2}$  at 400°C.  
What do you expect will happen?

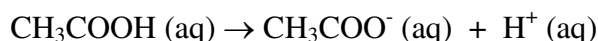
  - The reaction is at equilibrium so no net reaction occurs.
  - The reaction occurs in the reverse direction.
  - The reaction occurs in the forward direction.
  - The velocity of the reaction will increase.
  - It is impossible to predict without more information.
- A saturated solution of a metal salt can be assured if which of the following is true?

  - Additional solid, when added to the solution, does not immediately dissolve.
  - A clear solution is obtained after a large mass of solid is added to water.
  - The amount of solid calculated from the solubility has all dissolved.
  - When equilibrium is reached, there is still some of the solid present.
  - The solution becomes bright green in colour.

5. A saturated solution of lead iodide has a lead ion,  $\text{Pb}^{2+}$ , concentration of 0.0268 g/100mL. What is the solubility product of lead iodide?

A.  $2.68 \times 10^{-2}$   
B.  $7.18 \times 10^{-4}$   
C.  $1.93 \times 10^{-5}$   
D.  $2.16 \times 10^{-9}$   
E.  $8.65 \times 10^{-9}$

6. Acetic acid is a weak acid that dissociates according to the equation



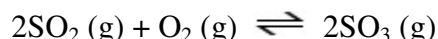
At equilibrium at  $25^\circ\text{C}$  a  $0.100 \text{ molL}^{-1}$  solution of acetic acid has the following concentrations:

$[\text{CH}_3\text{COOH}] = 0.0990 \text{ molL}^{-1}$   
 $[\text{CH}_3\text{COO}^-] = 1.33 \times 10^{-3} \text{ molL}^{-1}$   
 $[\text{H}^+] = 1.33 \times 10^{-3} \text{ molL}^{-1}$

The equilibrium constant for the ionisation of acetic acid is

A.  $1.33 \times 10^{-3}$   
B.  $1.77 \times 10^{-6}$   
C.  $1.79 \times 10^{-5}$   
D.  $5.65 \times 10^5$   
E.  $7.52 \times 10^2$

7. At 900 K, the equilibrium constant,  $K_p$ , for the following reaction is 0.345:



At equilibrium the partial pressure of  $\text{SO}_2$  is 35.0 atm and that of  $\text{O}_2$  is 15.9 atm. The partial pressure of  $\text{SO}_3$  in atm is

A.  $1.2 \times 10^{-2}$   
B.  $3.4 \times 10^{-1}$   
C. 51  
D. 82  
E. 672

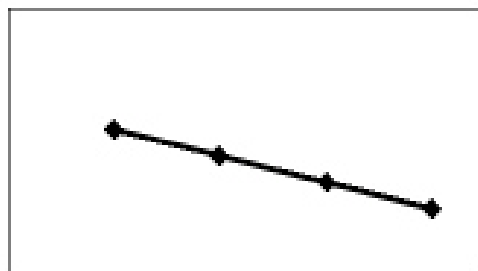
8. Calculate the pH of a solution that is  $0.295 \text{ molL}^{-1}$  in sodium formate ( $\text{NaHCO}_2$ ) and  $0.205 \text{ molL}^{-1}$  in formic acid ( $\text{HCOOH}$ ). The  $K_a$  for formic acid is  $1.77 \times 10^{-4}$ .

A. 3.59  
B. 3.75  
C. 3.91  
D. 4.96  
E. 10.10

9.  $K_a$  for nitrous acid is  $4.50 \times 10^{-4}$ . Calculate the percent ionisation of nitrous acid in a solution of concentration  $0.249 \text{ molL}^{-1}$ .
- A.  $4.50 \times 10^{-4}$   
B.  $2.12 \times 10^{-2}$   
C.  $1.81 \times 10^{-1}$   
D. 4.25  
E. 18.06
10. The weak acid HX has a  $K_a$  of  $1 \times 10^{-8}$ . 50 mL of HX of concentration  $0.10 \text{ molL}^{-1}$  are titrated with 50 mL of NaOH of concentration  $0.1 \text{ molL}^{-1}$ . Calculate the pH of the resulting solution.
- A. 4.5  
B. 7.0  
C. 8.0  
D. 10.35  
E. 12.28
11. The standard cell potential  $E_{\text{cell}}^0$  for the voltaic cell based on the reaction
- $$\text{Pb}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Pb}(\text{s})$$
- is 0.63 V. The cell potential for this reaction when  $[\text{Zn}^{2+}] = 1.0 \text{ M}$  and  $[\text{Pb}^{2+}] = 2.0 \times 10^{-4} \text{ M}$  is given by
- A. 0.41 V  
B. 0.63 V  
C. 0.85 V  
D. 0.52 V  
E. 0.74 V
12. An aqueous copper(II) sulphate solution is electrolysed for 45 minutes. A current of 3.2 A is used. What mass of copper is produced?  
Given  $F = 96485 \text{ C/mol e}^-$
- A. 0.95 g  
B. 1.9 g  
C. 2.8 g  
D. 4.6 g  
E. 5.5 g
13. The chlor-alkali industry is based on the electrolysis of aqueous NaCl. What are the products of this electrolysis?
- A. NaOH,  $\text{H}_2$ , and  $\text{Cl}_2$   
B. NaOH,  $\text{O}_2$ , and  $\text{Cl}_2$   
C. Na,  $\text{O}_2$   
D. NaOH,  $\text{H}_2$ , and  $\text{O}_2$   
E. Na and  $\text{Cl}_2$

14. Determine the pressure in a 0.34 L balloon if the temperature is 35°C and the balloon contains 0.0233 mol of an ideal gas.
- A.  $1.3 \times 10^3$  atm
  - B. 1.73 atm
  - C. 0.58 atm
  - D. 0.20 atm
  - E. 6.24 atm
15. Oxygen gas, O<sub>2</sub>, effuses through a barrier at a rate of 0.183 mL/minute. If an unknown gas effuses through the same barrier at a rate of 0.259 mL/minute, what is the molar mass of the gas?
- A. 16.0 g/mol
  - B. 20.8 g/mol
  - C. 28.0 g/mol
  - D. 44.01 g/mol
  - E. 64.0 g/mol
16. Determine the density of nitrogen gas at 21°C and 704 torr.
- A. 0.0384 g/L
  - B. 0.537 g/L
  - C. 0.816 g/L
  - D. 0.934 g/L
  - E. 1.07 g/L
17. Which statement concerning relative rates of reaction is correct for the chemical equation given below?
- $$2 \text{NOBr(g)} \rightarrow 2 \text{NO(g)} + \text{Br}_2 \text{(g)}$$
- A. The rate of disappearance of NOBr is equal to the rate of appearance of Br<sub>2</sub>.
  - B. The rate of disappearance of NOBr is two times the rate of appearance of NO.
  - C. The rate of disappearance of NOBr is half the rate of appearance of Br<sub>2</sub>.
  - D. The rate of appearance of NO is equal to the rate of appearance of Br<sub>2</sub>.
  - E. The rate of appearance of NO is two times the rate of appearance of Br<sub>2</sub>.
18. Which of the following statements is correct for the first-order reaction:
- $$\text{A} \rightarrow 2\text{B?}$$
- A. The concentration of A decreases linearly with respect to time.
  - B. The concentration of A is constant with respect to time.
  - C. The natural logarithm of the concentration of A decreases linearly with respect to time.
  - D. The rate of reaction is constant with respect to time.
  - E. The rate constant, *k*, of the reaction decreases linearly with respect to time.

19. A student analyzed a second-order reaction and obtained the graph below. Unfortunately, the student forgot to label the axes. What are the correct labels for the  $x$  and  $y$  axes?



- A.  $x$  axis = time,  $y$  axis =  $\ln[A]$   
B.  $x$  axis =  $\ln$  time,  $y$  axis =  $[A]$   
C.  $x$  axis =  $\ln[A]$ ,  $y$  axis =  $[A]$   
D.  $x$  axis = time,  $y$  axis =  $1/[A]$   
E.  $x$  axis =  $1/\text{time}$ ,  $y$  axis =  $1/[A]$
20. Among the following, identify the sentence that states a fact about equilibrium vapour pressure, followed by an acceptable explanation or reason for the fact.
- A. Vapour pressure decreases with temperature because the liquid expands and molecules are farther apart  
B. Vapour pressure increases with temperature because intermolecular attractions are weaker at higher temperatures  
C. Vapour pressure decreases with temperature because molecules stick together better when they are hot  
D. Vapour pressure increases with temperature because energy is distributed more efficiently at higher temperatures  
E. Vapour pressure increases with temperature because at higher temperatures a larger fraction of the molecules has sufficient energy to escape from the liquid state
21. If 86.5 g of ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) is added to 355 g of water, what is the mole fraction of ethanol?
- A. 0.00425  
B. 0.0870  
C. 0.0953  
D. 0.244  
E. 5.29
22. Which of the following aqueous solutions will have the lowest freezing point at 1 atm pressure?
- A. pure  $\text{H}_2\text{O}$   
B. 1m  $\text{MgBr}_2$   
C. 1m  $\text{RbI}$   
D. 1m  $\text{NH}_3$   
E. 1m  $\text{C}_6\text{H}_{12}\text{O}_6$

23. Colloids are described by all of the following **except**:
- A. The particles in a colloid are so small that settling is negligible.
  - B. The mixture appears cloudy.
  - C. Only combinations of liquids and gases can form colloids.
  - D. Colloids are not suspensions or homogeneous mixtures.
  - E. Mayonnaise, whipped cream and fog are all examples of colloids.
24. The Tyndall effect describes
- A. precipitation of colloidal particles using electrically charged plates
  - B. the adsorption of positive ions onto the surface of a hydrophilic solid
  - C. hydrophobic interactions between nonpolar molecules
  - D. the scattering of light by colloidal particles
  - E. the bending of light by particles dissolved in solution
25. Clouds and fog are colloidal dispersions that contain a liquid dispersed in a gaseous medium. This type of colloid is called a(n) \_\_\_\_\_
- A. emulsion
  - B. aerosol
  - C. foam
  - D. sol
  - E. gel

(25 x 2)

## **Section B**

Answer the following questions in the supplied answer book.

### **Question 26**

- (a) A swimming pool was sufficiently alkaline so that the carbon dioxide absorbed from the air produces a solution that was  $2 \times 10^{-4} \text{ molL}^{-1}$  in carbonate ion. The pool originally contained the following ions:

$$[\text{Mg}^{2+}] = 4 \times 10^{-3} \text{ molL}^{-1}$$

$$[\text{Ca}^{2+}] = 6 \times 10^{-4} \text{ molL}^{-1}$$

$$[\text{Fe}^{2+}] = 8 \times 10^{-7} \text{ molL}^{-1}$$

Given the  $K_{\text{sp}}$  values

$$\text{CaCO}_3 \quad K_{\text{sp}} = 4.7 \times 10^{-9}$$

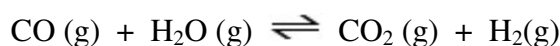
$$\text{MgCO}_3 \quad K_{\text{sp}} = 4.0 \times 10^{-5}$$

$$\text{FeCO}_3 \quad K_{\text{sp}} = 2.0 \times 10^{-11}$$

State whether any precipitates will form, identify them, and give reasons for your deductions.



- (b) The equilibrium constant for the reaction



is 0.49 at 1000°C. Suppose we start with 2.00 mol each of CO and H<sub>2</sub>O and 1 mol each of CO<sub>2</sub> and H<sub>2</sub> in a 50 L vessel. Calculate the reaction quotient, state whether the reaction will go left or right, and calculate the number of moles of each component at equilibrium.

5

### Question 27

A buffer solution is prepared by adding 500 mL of 0.10 molL<sup>-1</sup> acetic acid (K<sub>a</sub> = 1.75 × 10<sup>-5</sup>) to 300 mL of 0.20 molL<sup>-1</sup> sodium acetate.

- (a) Calculate the pH of the buffer solution. 4
- (b) Calculate the volume of 1.00 molL<sup>-1</sup> HCl that must be added to this buffer solution in order to lower its pH by one pH unit. 6

### Question 28

- (a) A solution of 0.25 mol of Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> dissolved in 375 g of water has a freezing point of -1.02 °C. Determine the
- degree of dissociation of the Fe<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>.
  - boiling point of the solution.
- Given : k<sub>F</sub> (water) = 1.853 °C/m  
Given : k<sub>B</sub> (water) = 0.515 °C/m 6
- (b) Calculate the osmotic pressure, in Pa, of an aqueous 2 % (mass/volume) solution of sucrose (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>) at 20.0 °C. 4

### Question 29

- (a) In a first order reaction the half-life for ethyl bromide (EtBr) at 700K is 650s
- Find the rate constant. 1
  - Determine the time in hours required for the [EtBr] to drop from 0.050 M to 0.0125 M. 2
  - Determine the [EtBr] two hours after the time elapsed in (ii). 3

- (b) Some results for the rate of a reaction between two substances A and B are shown here:

[A]/mol dm <sup>-3</sup>	[B]/mol dm <sup>-3</sup>	Rate/mol dm <sup>-3</sup> s <sup>-1</sup>
1.4 x 10 <sup>-2</sup>	2.3 x 10 <sup>-2</sup>	7.4 x 10 <sup>-9</sup>
2.8 x 10 <sup>-2</sup>	4.6 x 10 <sup>-2</sup>	5.92 x 10 <sup>-8</sup>
2.8 x 10 <sup>-1</sup>	4.6 x 10 <sup>-2</sup>	5.92 x 10 <sup>-6</sup>

Determine the overall order and rate constant for the reaction.

4

### Question 30

- (a) Use the following standard state cell potentials to calculate the solubility product constant,  $K_{sp}$  at 25°C for Mg(OH)<sub>2</sub>:

Given  $F = 96485 \text{ C/mol } e^-$



4

- (b) Calculate the ratio of ion concentrations of Mg<sup>2+</sup> and Cu<sup>2+</sup> necessary to produce a voltaic cell with an emf of 2.69 V. The electrodes are solid magnesium and solid copper.

Given:



6

# PERIODIC CHART OF THE ELEMENTS

IA (1)		IIA (2)												IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	0 (18)														
				atomic number																													
				symbol																													
				atomic mass																													
1	<b>H</b> 1,01	2	<b>He</b> 4,00																														
3	<b>Li</b> 6,94	4	<b>Be</b> 9,01																														
11	<b>Na</b> 23,0	12	<b>Mg</b> 24,3																														
19	<b>K</b> 39,1	20	<b>Ca</b> 40,1																														
37	<b>Rb</b> 85,5	38	<b>Sr</b> 87,6																														
55	<b>Cs</b> 132,9	56	<b>Ba</b> 137,3																														
87	<b>Fr</b> (223)	88	<b>Ra</b> 226,0																														
				IIIB (3)			IVB (4)			VB (5)			VIB (6)			VIIB (7)			VIII (8-10)			IIB (12)											
21	<b>Sc</b> 45,0	22	<b>Ti</b> 47,9	23	<b>V</b> 50,9	24	<b>Cr</b> 52,0	25	<b>Mn</b> 54,9	26	<b>Fe</b> 55,9	27	<b>Co</b> 58,9	28	<b>Ni</b> 58,7	29	<b>Cu</b> 63,4	30	<b>Zn</b> 65,4	31	<b>Ga</b> 69,7	32	<b>Ge</b> 72,6	33	<b>As</b> 74,92	34	<b>Se</b> 79,0	35	<b>Br</b> 79,9	36	<b>Kr</b> 83,8		
39	<b>Y</b> 88,9	40	<b>Zr</b> 91,2	41	<b>Nb</b> 92,9	42	<b>Mo</b> 95,9	43	<b>Tc</b> (98)	44	<b>Ru</b> 101,1	45	<b>Rh</b> 102,9	46	<b>Pd</b> 106,4	47	<b>Ag</b> 107,9	48	<b>Cd</b> 112,4	49	<b>In</b> 114,8	50	<b>Sn</b> 118,7	51	<b>Sb</b> 121,6	52	<b>Te</b> 127,6	53	<b>I</b> 127,9	54	<b>Xe</b> 131,3		
57	<b>La</b> 138,9	72	<b>Hf</b> 178,5	73	<b>Ta</b> 180,9	74	<b>W</b> 183,9	75	<b>Re</b> 186,2	76	<b>Os</b> 190,2	77	<b>Ir</b> 192,2	78	<b>Pt</b> 195,1	79	<b>Au</b> 197,0	80	<b>Hg</b> 200,6	81	<b>Tl</b> 204,4	82	<b>Pb</b> 207,2	83	<b>Bi</b> 209,0	84	<b>Po</b> (209)	85	<b>At</b> (210)	86	<b>Rd</b> (222)		
89	<b>Ac</b> 227,0	104	<b>Db</b> (261)	105	<b>Jl</b> (262)	106	<b>Rf</b> (263)	107	<b>Bh</b> (262)	108	<b>Hn</b> (265)	109	<b>Mt</b> (266)																				
				* lanthanides				# actinides																									
58	<b>Ce</b> 140,1	59	<b>Pr</b> 140,9	60	<b>Nd</b> 144,2	61	<b>Pm</b> (145)	62	<b>Sm</b> 150,4	63	<b>Eu</b> 152,0	64	<b>Gd</b> 157,3	65	<b>Tb</b> 158,9	66	<b>Dy</b> 162,5	67	<b>Ho</b> 164,9	68	<b>Er</b> 167,3	69	<b>Tm</b> 168,9	70	<b>Yb</b> 173,0	71	<b>Lu</b> 175,0						
90	<b>Th</b> 232,0	91	<b>Pa</b> 231,0	92	<b>U</b> 238,0	93	<b>Np</b> 237,0	94	<b>Pu</b> (244)	95	<b>Am</b> (243)	96	<b>Cm</b> (247)	97	<b>Bk</b> (247)	98	<b>Cf</b> (251)	99	<b>Es</b> (252)	100	<b>Fm</b> (257)	101	<b>Md</b> (258)	102	<b>No</b> (258)	103	<b>Lr</b> (260)						

SURNAME \_\_\_\_\_ INITIALS \_\_\_\_\_ STUDENT NO \_\_\_\_\_

COURSE : AC/CE \_\_\_\_\_

Answer sheet - Section A

MAIN STREAM/ ECP \_\_\_\_\_

Please mark the correct answer with a "X" in the appropriate space for Question 1 to 25.

Question					
1.	A	B	C	D	E
2.	A	B	C	D	E
3.	A	B	C	D	E
4.	A	B	C	D	E
5.	A	B	C	D	E
6.	A	B	C	D	E
7.	A	B	C	D	E
8.	A	B	C	D	E
9.	A	B	C	D	E
10.	A	B	C	D	E
11.	A	B	C	D	E
12.	A	B	C	D	E
13.	A	B	C	D	E
14.	A	B	C	D	E
15.	A	B	C	D	E
16.	A	B	C	D	E
17.	A	B	C	D	E
18.	A	B	C	D	E
19.	A	B	C	D	E
20.	A	B	C	D	E
21.	A	B	C	D	E
22.	A	B	C	D	E
23.	A	B	C	D	E
24.	A	B	C	D	E
25.	A	B	C	D	E