LAST NAME: Rogers
FIRST NAME: answer key
SIGNATURE:
STUDENT ID#:

Course: CHEMISTRY	**Number:** 206 /4	**Sections:** 01 & 52	
Instructor: C.W. Rogers			
Examination: Final	**Date:** 17 April, 2013	**Time:** 19:00- 22:00	**# of pages:** 14 (7 both sides)

Materials Allowed: A data sheet and periodic table are attached to this paper - *no other materials are allowed.* You may tear off the data sheet and periodic table if you wish. Leave all other pages attached.

Calculators Allowed: Yes (But NO OTHER ELECTRONICS are allowed, except a wrist-watch.)

Special Instructions:

PLEASE READ THIS PAGE WHILE YOU WAIT TO START.

- **Check that your exam has 7 pages (p.1-14, double-sided). Write your ID # on all pages.**
- **Read through the whole exam thoroughly BEFORE starting. Please note the following:**
  - There are three sections to this exam. Please read each section's instructions carefully.
  - For full marks: you must show formulae, units & comments to explain your calculations.
  - On p.5 & p.9: on each of these pages, answer one question (others not graded).
- **Write all answers legibly in the space provided (use pages 10-12 for extra space).**
- **Suggestions: Read the whole exam before starting, & do what feels easy first.**
  Spend 20 min / page to have 20 minutes left to check your work.
- **PLEASE RAISE YOUR HAND IF YOU NEED CLARIFICATION.**

Please leave this area blank:

Mark breakdown:

Page 2.	/ 12
Page 3	/ 12
Page 4.	/ 12
Page 5.	/ 6
Page 6.	/ 10
Page 7.	/ 10
Page 8.	/ 10
Page 9.	/ 10

TOTAL: / 80 (MAXIMUM 82)

CHEM 206 W2013 Sect 01 & 52 Final Examination ID #: answer key

Section I.

The following 18 questions are multiple choice, worth 2 marks each. There is ONE correct choice for each question, with no penalty for incorrect answers. Rough work will not be marked. Enter your answers in PENCIL on the computer-gradable sheet provided. Do not forget to fill in the circles for your name and ID.

For questions 1-6: Consider the chemical/physical process shown to the right of each question.

#1. Which choice correctly describes the reaction shown?

$C_8H_{18}(g) + {}^{25}/_{2}\,O_2(g) \rightarrow 8\,CO_2(g) + 9\,H_2O(g)$

D

a. $w_{sys} > 0$, because work done by surroundings ✗
b. $w_{sys} < 0$, because work done by surroundings ✗
c. $w_{sys} > 0$, because work done by system ✓
[✓ d.] $w_{sys} < 0$, because work done by system ✓
e. $w_{sys} = 0$, because no work involved ✗

13.5 mol gas → 17 mol gas
system expands (does work)
system expends energy (−)

#2. Which choice correctly describes the process shown?

$H_2O(g) \rightarrow H_2O(l)$

E

a. ✗ $\Delta H° > 0$, so disorder of surroundings decreases
b. ✗ $\Delta H° > 0$, so disorder of surroundings increases
c. ✗ $\Delta H° = 0$, so disorder of surroundings unaffected
d. $\Delta H° < 0$, so disorder of surroundings decreases ✗
[✓ e.] $\Delta H° < 0$, so disorder of surroundings increases ✓

condensation
IM forces form
exothermic ($\Delta H° < 0$)
heat released to surr.

#3. Which choice correctly describes the equilibrium shown?

$O_2(g) \rightleftharpoons O_2(aq)$

B

a. ✗ forward process favoured when vapour pressure of H_2O ? is high
[✓ b.] forward process favoured when partial pressure of O_2 is high ←
c. ✗ forward process involves formation of dipole-dipole forces ✗
d. ✗ forward process involves formation of covalent bonds ✗
e. ✗ forward process favoured when temperature is high ✗

gas dissolving in water
higher solubility when
P_{O_2} is larger
&, T is smaller.

#4. Which choice correctly describes the process shown?

$H_2O(l) \rightarrow H_2O(s)$ at 25°C

D

a. ✗ $\Delta G° < 0$ AND $\Delta S°_{univ} < 0$
b. ✗ $\Delta G° < 0$ AND $\Delta S°_{univ} > 0$
c. ✗ $\Delta G° = 0$ AND $\Delta S°_{univ} = 0$
[✓ d.] $\Delta G° > 0$ AND $\Delta S°_{univ} < 0$
e. $\Delta G° > 0$ AND $\Delta S°_{univ} > 0$

water freezing at 25°C?
non-spontaneous ($\Delta G° > 0$)
$\therefore \Delta S°_{univ} < 0$ ($\Delta G°_{sys} \equiv -T\Delta S°_{univ}$)

#5. Which choice correctly describes the equilibrium shown?

$C(s) + CO_2(g) \rightleftharpoons 2\,CO(g)$

C

a. ✗ heterogeneous reaction, $K_c = [CO]^2 / [C][CO_2]$
b. ✗ homogeneous reaction, $K_c = [CO]^2 / [C][CO_2]$
[✓ c.] heterogeneous reaction, $K_c = [CO]^2 / [CO_2]$
d. ✗ homogeneous reaction, $K_c = [CO]^2 / [CO_2]$
e. heterogeneous reaction, $K_c = [CO_2] / [CO]^2$ — upside-down

heterogeneous.

$K_c = \frac{[CO]^2}{[CO_2]}$ don't include solid

#6. Which choice correctly describes the reaction shown?

$HOI(aq) + NH_3(aq) \rightleftharpoons OI^-(aq) + NH_4^+(aq)$

A

[✓ a.] a lot of both reactants and products at equilibrium
b. ✗ quantitative product formation (*i.e.*, 100% yield)
c. ✗ strongly reactant-favoured at equilibrium
d. ✗ strongly product-favoured at equilibrium
e. ✗ no reaction at all

← CB	Species	K_a	
stronger OI^-	HOI	2.3×10^{-11}	weaker acid
weaker NH_3	NH_4^+	5.6×10^{-10}	stronger acid

[redacted]

at eqm, lots of reactants + lots of products ⟸ slight preference for OI^- holding H^+ ⟸ BUT BOTH VERY WEAK + NOT VERY

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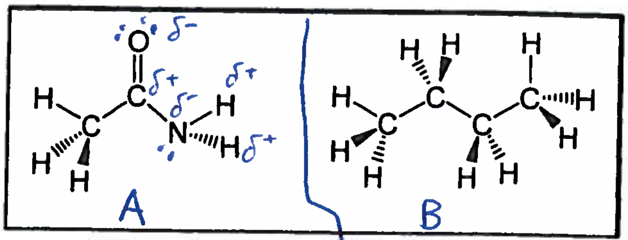
For questions 7-9: Consider molecules A & B in the box.



- polar
- H-bond donors (2) + acceptors (2)
- MM = 59.07 g/mol

- nonpolar
- MM = 58.12 g/mol

#7. Which choice best summarizes the intermolecular forces acting in a pure sample of substance **B**?

D

a. ✗ hydrogen bonding, dipole-dipole & London dispersion forces
b. ✗ hydrogen bonding & London dispersion forces
c. ✗ hydrogen bonding & dipole-dipole forces
[✓ d.] London dispersion forces only
e. dipole-dipole forces only

#8. Which choice best describes the expected relative boiling points (bp) of pure **A** versus pure **B**?

A

[✓ a.] bp(A) > bp(B), because intermolecular forces in pure A are stronger than in pure B ✓
b. bp(A) < bp(B), because intermolecular forces in pure A are stronger than in pure B ✓
c. ✗ bp(A) > bp(B), because intermolecular forces in pure A are weaker than in pure B ✗
d. ✗ bp(A) < bp(B), because intermolecular forces in pure A are weaker than in pure B ✗
e. ✗ bp(A) ≈ bp(B), because A & B have nearly identical molar masses not relevant unless have similar TYPES of IM forces.

#9. Which choice(s) best describes the expected solubility of substances **A** and **B** in water?

)

a. ✓ A has high solubility in water, because strengths of A ↔ H_2O forces ≈ H_2O ↔ H_2O forces
b. ✓ B has low solubility in water, because strengths of H_2O ↔ H_2O forces >> B ↔ H_2O forces
c. ✗ B has low solubility in water, because strengths of B ↔ B forces >> B ↔ H_2O forces
[✓ d.] both a and b
e. ✗ both a and c

id-id vs id-d

stronger

For questions 10-12: The reaction of ozone and nitric oxide is involved in the formation of smog:

$$O_3(g) + NO(g) \rightarrow NO_2(g) + O_2(g)$$

The reaction is first order in NO and in O_3, with rate constant of 82 $M^{-1}\ s^{-1}$ at 25°C and 3100 $M^{-1}\ s^{-1}$ at 75°C.

rate = $k[NO][O_3]$ $T_1 = 298.15\ K$ $T_2 = 348.15\ K$

#10. Is the reaction order consistent with this reaction following a single-step reaction mechanism?

B

a. ✗ Cannot tell, because the reaction involves four molecules but only two orders were given. reactants only!
[✓ b.] Yes, because bimolecular elementary steps are first order in each molecule involved.
c. No, because bimolecular elementary steps are first order in each molecule involved.
d. Yes, because unimolecular elementary steps are first order.
e. No, because unimolecular elementary steps are first order.

#11. What is the rate of the reaction at 25°C when [NO] = 3.0×10^{-6} M and [O_3] = 5.0×10^{-9} M?

A

[✓ a.] $1.2\times10^{-12}\ M\ s^{-1}$
b. $4.7\times10^{-11}\ M\ s^{-1}$
c. $4.1\times10^{-7}\ M\ s^{-1}$
d. $2.5\times10^{-4}\ M\ s^{-1}$
e. not enough information

$$\text{rate} = k[NO][O_3]$$
$$= (82\ M^{-1}s^{-1})(3.0\times10^{-6}\ M)(5.0\times10^{-9}\ M)$$
$$= 1.23\times10^{-12}\ M\cdot s^{-1}$$
$$\therefore \text{rate} = 1.2\times10^{-12}\ M\cdot s^{-1}$$

#12. What is the activation energy of the reaction?

D

a. 11 J
b. 620 J
c. 1100 J
[✓ d.] 63000 J
e. 650000 J

$$k = Ae^{-E_a/RT}$$
$$\Rightarrow \ln k = \ln A - E_a/RT$$
for 2 Ts ⇒
$$\ln k_1 - \ln k_2 = \cancel{\ln A} - \cancel{\ln A} - (E_a/RT_1) + (E_a/RT_2)$$
$$\ln\left(\frac{k_1}{k_2}\right) = -\frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$E_a = \frac{-R\ln\left(\frac{k_1}{k_2}\right)}{\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$
$$= \frac{-8.314\ln\left(\frac{82}{3100}\right)}{\frac{1}{298.15} - \frac{1}{348.15}}$$

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For questions 13-18: The reaction below is a possible synthetic route to methanol, which is used as a fuel:

$C(s) + \frac{1}{2} O_2(g) + 2 H_2(g) \rightleftharpoons CH_3OH(l)$ *where* $\Delta H^\circ_{rxn} = -238.4$ kJ per mol-rxn exothermic
& $\Delta S^\circ_{rxn} = -242.3$ J/K per mol-rxn at 298 K.
decrease in disorder

#13. Which choice correctly describes this reaction?

a. X similar bond strengths in products & reactants AND similar disorder in products & reactants
b. x stronger bonding in reactants AND products more disordered than reactants
E c. x stronger bonding in reactants AND reactants more disordered than products
d. stronger bonding in products AND products more disordered than reactants x
[✓ e.] stronger bonding in products AND reactants more disordered than products

#14. What is the standard Gibbs' free energy for this reaction at 298 K?

a. +71981.9 kJ/mol-rxn
b. +4.0 kJ/mol-rxn
C [✓ c.] -166.2 kJ/mol-rxn
d. -238.4 kJ/mol-rxn
e. -480.7 kJ/mol-rxn

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$
$= -238.4 \text{ kJ} - (298\text{K})(-0.2423 \text{ KJ/K})$
$\therefore \Delta G^\circ = -166.2 \text{ kJ}$ very spontaneous forward

#15. What is the value of the equilibrium constant for this reaction at 298 K?

a. X 2.411×10^{-13}
b. X 1.069
D c. X 8.947×10^{2}
[✓ d.] 1.359×10^{29}
e. 6.155×10^{41}

$\Delta G^\circ = -RT\ln K$
$\therefore \ln K = \frac{-\Delta G^\circ}{RT}$ $\rightarrow$ $K = e^{-\Delta G^\circ/RT}$
$= e^{+(166200\text{ J})/(8.314 \text{ J/mol}\cdot\text{K} \times (298\text{K}))}$
$\therefore K = 1.359\times10^{+29}$ (HUGE!)

#16. If this reaction is initially at equilibrium, how will the system change if a contaminant is added to the reaction mixture that selectively consumes some of the $H_2(g)$? reactant

a. Q < K, thus system shifts right until re-establishes equilibrium x
D b. Q > K, thus system shifts right until re-establishes equilibrium x
c. Q < K, thus system shifts left until re-establishes equilibrium
[✓ d.] Q > K, thus system shifts left until re-establishes equilibrium
e. no change, because reaction started at equilibrium x

$Q = \frac{[CH_3OH]}{[O_2]^{1/2}[H_2]^2}$

#17. If this reaction is initially at equilibrium, how will the system change if the container's volume suddenly increases? conc and partial P of all gases $\downarrow\downarrow$, fwd direction slows more ...

a. rate of forward reaction initially slower, thus system shifts right until re-establishes equilibrium X
C b. x rate of forward reaction initially faster, thus system shifts right until re-establishes equilibrium
[✓ c.] rate of forward reaction initially slower, thus system shifts left until re-establishes equilibrium
d. x rate of forward reaction initially faster, thus system shifts left until re-establishes equilibrium
e. X no change, because reaction started at equilibrium

#18. If this reaction is initially at equilibrium, how will the system change if the temperature suddenly increases?

a. X yields more products, because reaction is entropically unfavourable
B [✓ b.] yields less products, because reaction is entropically unfavourable
c. X yields more products, because reaction is entropically favourable
d. yields less products, because reaction is entropically favourable
e. X no change, because reaction started at equilibrium

$\Delta S^\circ < 0$ (unfav.)
$\therefore$ higher yield of prod. at lower T...

$\therefore$ lower yield at higher T

REMAINDER
OF ANSWERS
UNAVAILABLE