

LAST NAME:

Rogers

FIRST NAME:

answer key

STUDENT ID:

(45 std left early)

## Chem 205 - GENERAL CHEMISTRY I

### MIDTERM EXAMINATION

**PLEASE READ THIS BOX WHILE WAITING TO START**

**INSTRUCTIONS:**

- Calculators are permitted; cell phones and other electronic devices are not allowed.
- This test paper includes 9 pages; please read over the whole test before starting.
- A periodic table (incomplete) is included and may be detached (not graded).
- Fill in your name & ID # on scansheet, in pencil (fill circles completely).
- Please write clearly and organize your work logically.
- Read the instructions to each section carefully.
- **Duration: 70 minutes. GOOD LUCK!**

78 students wrote

Professor use - Grades:

Pages 2-4:  $29.9 / 40 = 74.9\%$

Page 5:  $5.0 / 11 = 45.1\%$  !

TOTAL:  $34.9 / 50$  (MAX. 51)

PERCENT:  $69.8\%$

**PART A: MULTIPLE-CHOICE QUESTIONS – 2 marks each**  
Colour in final answer on scansheet, in pencil. Circle answer here too, as a backup.

~~\*~~ = most commonly wrong

# 1. Which is the best description of the change involved when sodium chloride (NaCl) dissolves in water?

- B
- a) ~~x~~ It is a chemical change, because the ions change their charges when they dissolve.
  - b)** It is a physical change, because the ions dissociate but do not change charges.
  - c) ~~x~~ It is a chemical change, because heat is needed for the process to occur.
  - d) ~~x~~ It is a physical change, because the solid NaCl melts to become liquid.

# 2. Which one of the important historical experiments listed below did not give the results described?

- C
- a) ~~T~~ The Curies' experiments with radioactivity proved that atoms are made up of smaller particles.
  - b) ~~T~~ Thomson's experiments showed that atoms contain negatively charged particles (electrons).
  - c) F** Rutherford's experiments proved that Thomson's plum-pudding model of the atom is correct.
  - d) ~~T~~ Millikan's oil-drop experiment showed that the charge on any particle is a whole-number multiple of the electron charge.

# 3. How many protons, neutrons, and electrons are in a  $^{58}\text{Fe}^{3+}$  cation?

- C
- a) ~~x~~ 26 p<sup>+</sup>, 32 n<sup>0</sup>, 26 e<sup>-</sup>
  - b) ~~x~~ 32 p<sup>+</sup>, 26 n<sup>0</sup>, 32 e<sup>-</sup>
  - c) ✓** 26 p<sup>+</sup>, 32 n<sup>0</sup>, 23 e<sup>-</sup>
  - d) ~~x~~ 32 p<sup>+</sup>, 26 n<sup>0</sup>, 29 e<sup>-</sup>
- $z = 26 \text{ p}^+$  with 3 fewer e<sup>-</sup> (= +3 charge)  
 $n = 58 - 26 = 32 \text{ n}^0$

# 4. An element (E) has several isotopes, with these abundances: 54.5%  $^{72}\text{E}$ , 15.6%  $^{73}\text{E}$ , 29.9%  $^{74}\text{E}$ . What is the most reasonable atomic weight for this element?

- B
- a) 72.1 g/mol
  - b)** 72.8 g/mol
  - c) 73.4 g/mol
  - d) 73.8 g/mol
- $0.545(72) + 0.156(73) + 0.299(74) = 72.754$   
 $= 72.8 \text{ g/mol}$  (3SF)

# 5. Which one of the following statements about ionic compounds is incorrect?

- C
- a) ~~T~~ Ionic compounds form extended 3-dimensional networks called crystal lattices.
  - b) ~~T~~ Positive and negative ions are attracted to each other by electrostatic forces.
  - c) F** As the ion charges increase, the attraction between the ions decreases.
  - d) ~~T~~ Ionic crystals tend to be rigid, and they cleave along planes.
- $E \propto - \frac{Q_1 Q_2}{r}$

# 6. What is the balanced chemical equation when  $\text{BF}_3$  and  $\text{H}_2\text{O}$  react to produce  $\text{B}_2\text{O}_3$  and  $\text{HF}$ ?

- D
- a) ~~x~~  $\text{BF}_3(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + \text{HF}(\text{g})$
  - b) ~~x~~  $2 \text{BF}_3(\text{g}) + 3 \text{H}_2\text{O}(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 3 \text{HF}(\text{g})$
  - c) ~~x~~  $\text{BF}_3(\text{g}) + 3 \text{H}_2\text{O}(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 3 \text{HF}(\text{g})$
  - d) ✓**  $2 \text{BF}_3(\text{g}) + 3 \text{H}_2\text{O}(\text{g}) \rightarrow \text{B}_2\text{O}_3(\text{s}) + 6 \text{HF}(\text{g})$

~~\*~~ # 7. An analysis was performed to find the concentration of a NaOH solution, with the following results:

Trial	Concentration (M)	deviation	avg devn	avg conc	rel. error (ACCURACY)
1	0.69 ± 0.02	0	= 0.05 ⇒ $(\frac{0.05}{0.69}) \times 100\% = 7.2\% \approx 7.5\%$	= 0.69	= $\frac{ 0.69 - 0.70 }{0.70} \times 100\%$ = 1.4% < 5% ✓
2	0.76 ± 0.02	0.07			
3	0.61 ± 0.02	0.08			

If the actual concentration of NaOH was 0.70 M, which choice best describes the analysis data?

- B
- a) ~~x~~ precise – the average deviation of the concentrations from trials 1-3 is < 5% NO
  - b) ✓** accurate – the relative error of the concentrations from trials 1-3 is < 5% YES.
  - c) ~~x~~ neither (a) nor (b)
  - d) ~~x~~ both (a) and (b)

\* # 8. In which set of compounds below are all the compounds insoluble in water?

- a) X  $\text{Na}_2\text{CO}_3$ ,  $\text{CaCO}_3$ ,  $(\text{NH}_4)_2\text{CO}_3$
- b) X  $(\text{NH}_4)_2\text{S}$ ,  $\text{FeS}$ ,  $\text{Na}_2\text{SO}_4$
- c) X  $\text{NH}_4\text{Cl}$ ,  $\text{KNO}_3$ ,  $\text{NaOH}$
- d) X  $\text{NaCl}$ ,  $\text{AgCl}$ ,  $\text{ZnCl}_2$
- e)  $\text{ZnS}$ ,  $\text{NiS}$ ,  $\text{CaCO}_3$  all insoluble

NOT soluble  
Soluble: salts of alkali metals,  $\text{NH}_4^+$   
nitrates, chlorates, acetates  
halides EXCEPT...  
sulfates EXCEPT...

E

# 9. When water is boiling, bubbles rise to the surface. What do the bubbles contain?

- a) air (mostly  $\text{N}_2$  and  $\text{O}_2$  gases)  $\Rightarrow$  when just warming up, yes, but all gone by time it BOILS.
- b) nothing (a vacuum)
- c)  $\text{H}_2$  and  $\text{O}_2$  gases
- d)  $\text{H}^+$  and  $\text{OH}^-$  ions
- e)  $\text{H}_2\text{O}$  vapour  $\Rightarrow$  composition of substance's building blocks do NOT change (physical change)

E

implies water REACTS / DECOMPOSES when it boils

# 10. Which one of the following statements is not true?

- a) T When two soluble salts are mixed together, an insoluble salt may form and precipitate.
- b) F When a molecular compound is dissolved in water, covalent bonds are broken. ?! no, just weak intermolecular forces between molecules break
- c) T When two metals mix together, a solid solution called an alloy is formed.
- d) T When a metal reacts with a nonmetal, an ionic compound is formed.
- e) T When two nonmetals react, a covalent compound is formed.

B

\* # 11. Which ionic compound in the list below is not possible?

- a)  $\checkmark$   $(\text{NH}_4)_3\text{PO}_4$   $3\text{NH}_4^+ : 1\text{PO}_4^{3-}$
- b)  $\checkmark$   $\text{Fe}(\text{ClO}_4)_2$   $1\text{Fe}^{2+} : 2\text{ClO}_4^-$
- c)  $\checkmark$   $\text{LiHCO}_3$   $1\text{Li}^+ : 1\text{HCO}_3^-$
- d)  $\checkmark$   $\text{CaSO}_4$   $1\text{Ca}^{2+} : 1\text{SO}_4^{2-}$
- e) X  $\text{K}_2\text{NO}_3$   $2\text{K}^+ : 1\text{NO}_3^-$

ions with incorrect charges  
OR charges do not add up to zero (real compounds' formula units are neutral)

E

# 12. Fill in the blank: The statement "the total mass of materials is not affected by a chemical change in those materials" is called a(n) \_\_\_\_\_.

- a) X experiment = controlled set of observations to test a hypothesis
- b) observation  $\rightarrow$  but seen so many times, it ALWAYS occurs  $\therefore$  a LAW.
- c) natural law = the way things always happen / behave
- d) X hypothesis = proposed expected result
- e) X theory = tested model that explains behaviour

C

# 13. A piece metal with a mass of 33.2 g is submerged in 10.0 mL of water in a graduated cylinder and the volume rose to 22.3 mL. What is the identity of the metal?

- a) magnesium,  $1.74 \text{ g/cm}^3$
- b) aluminum,  $2.70 \text{ g/cm}^3$
- c) copper,  $8.96 \text{ g/cm}^3$
- d) silver,  $10.5 \text{ g/cm}^3$
- e) iron,  $7.87 \text{ g/cm}^3$

$$d = \frac{m}{V}$$

$$= \frac{33.2\text{g}}{(22.3 - 10.0)\text{mL}}$$

$$= 2.70 \text{ g/mL}$$

B

# 14. Which one of the following compounds is named incorrectly?

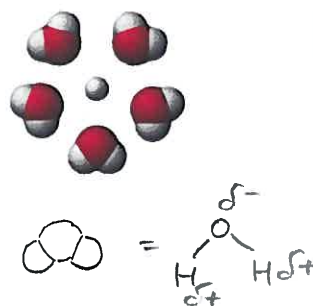
- A
- a) P<sub>2</sub>O<sub>5</sub>, phosphorus oxide      covalent ⇒ diphosphorus pentoxide
  - b) FeSO<sub>4</sub>, iron (II) sulfate      ionic ✓
  - c) CO, carbon monoxide      covalent ✓
  - d) Li<sub>2</sub>S, lithium sulfide      ionic ✓
  - e) NH<sub>3</sub>, ammonia      common name (like for water, H<sub>2</sub>O...)

# 15. The melting point of indium metal is 156.2°C. At 434.8 K, what is the physical state of indium?

- C
- a) a mixture of solid, liquid and gas
  - b) a mixture of solid and liquid
  - c) liquid
  - d) solid
  - e) gas
- m.p. = (156.2 + 273.15) = 429.4 K  
sample of metal at 434.8 K  
just above m.p. ∴ MELTED.

# 16. Which statement about this dissolved ion surrounded by water molecules is correct?

- B
- a) F The water molecules direct their O atoms towards the ion because the water molecules pack together more efficiently that way. Not relevant.
  - b) T Based on the orientation of the water molecules, we know that the ion has positive charge. → δ- O atoms aimed at ion! (attraction)
  - c) F Based on the orientation of the water molecules, we know that the ion has negative charge. would repel, not attract
  - d) More than one of the above statements are true.
  - e) All of the above statements are wrong.



# 17. Which element below is too reactive with air and water to be found in nature in its elemental form?

- A
- a) potassium = alkali metal, found only in chemistry labs!
  - b) nitrogen = major component of air
  - c) helium = minor component of air
  - d) sulfur = found at volcano vents
  - e) gold = found in rock if you are lucky
- } both extremely non reactive

# 18. Which of the following descriptions of elements (in their elemental forms) is incorrect?

- D
- a) ✓ Oxygen is a diatomic gas that causes metals to corrode and organic materials to burn.
  - b) ✓ Sodium is a soft silvery metal made of atoms packed together to form a solid.
  - c) ✓ Carbon has 3 allotropes: diamond, graphite and Buckminsterfullerene (C<sub>60</sub>).
  - d) F Hydrogen is a highly flammable gas that is made of free atoms.
  - e) ✓ Mercury is the only metal that is liquid at room temperature.

# 19. A particular hydrocarbon has the empirical formula CH<sub>2</sub>. If its molar mass is 140.3 g/mol, what is its molecular formula?

- E
- a) CH<sub>2</sub>
  - b) C<sub>3</sub>H<sub>6</sub>
  - c) C<sub>5</sub>H<sub>10</sub>
  - d) C<sub>8</sub>H<sub>16</sub>
  - e) C<sub>10</sub>H<sub>20</sub> = (CH<sub>2</sub>) × 10
- empirical mass 12.01  
+ 2(1.008)      and      140.3 g/mol ÷ 10  
14.026 g/mol      of CH<sub>2</sub>      14.026 g/mol      ↑  
real formula is (CH<sub>2</sub>) × 10

# 20. Which statement correctly describes a strong electrolyte?

- B
- a) X a substance that dissociates partially in water to yield a small concentration of ions = weak electrolyte
  - b) ✓ a substance that dissociates fully in water to yield a high concentration of ions
  - c) X a substance that dissolves fully in water to yield hydrated neutral molecules
  - d) X a substance that does not dissolve in water but conducts electricity
  - e) X a substance that generates its own electric current when melted
- ?!  
?

✓ = 1 mark  
 ✗ = 0.5 mark

$$MM = \frac{m}{n}$$

$$\Rightarrow n = \frac{m}{MM}$$

**PART B: SHOW COMPLETE WORK TO GET FULL CREDIT (answer on exam)**

# 21. (5 marks) Epsom salts is a hydrated ionic compound with the formula:  $MgSO_4 \cdot xH_2O$ . A 4.93 g sample of Epsom salt was heated to drive off the water of hydration, and the mass of the sample after complete dehydration was 2.41 g. Find the number of waters of hydration (x) in Epsom salt. Show full calculations and explanatory key words for each step. WORTH 1 POINT

5

or other expl. MM = ?  
 formula meaning

$MgSO_4 \cdot xH_2O (s) \xrightarrow{\text{heat}} MgSO_4 (s) + xH_2O (g)$

hydrated  $m = 4.93g$   
 anhydrous  $m = 2.41g$   
 driven off by heating  $m = 4.93 - 2.41 = 2.52g$

MM = ?  
 MM = 24.31  
 32.07  
 4(15.999)  
 120.38 g/mol

MM = 2(18.015)  
 36.03 g/mol

15.999  
 18.015 g/mol

$\Rightarrow n = 0.020020$  mol  $MgSO_4$   
 $n = 0.13988$  mol  $H_2O$

(2.5)

NOTE: do not round prematurely (show 1-2 extra SFs, even if zeroes, until end)

Compound formula is mole ratio (atom to atom ratio, not mass),  
 so  $\frac{1 MgSO_4}{0.020020 \text{ mol}} = \frac{x H_2O}{0.13988 \text{ mol}}$  (because  $MgSO_4 \cdot xH_2O$   
 1 mole x moles)

(2)

$0.020020x = 0.13988$   
 to 3 SF,  $x = 6.99$   
 but whole #s go in formulae  $\Rightarrow x = 7$

math conclusion

Thus, Epsom salts has 7 waters of hydration:  
 $MgSO_4 \cdot 7H_2O$

# 22. One way to soften "hard" water (which contains dissolved  $Ca^{2+}$  and  $Mg^{2+}$  ions, like Montreal's water) is to add a soluble phosphate salt to precipitate out the calcium and magnesium ions. Imagine you add 125 mL of 0.50 M  $Na_3PO_4$  to hard water that contains dissolved  $CaCl_2$  (ignore  $Mg^{2+}$  here for simplicity).

a) (2 marks) Write the net ionic equation for the reaction when aqueous  $Na_3PO_4$  and  $CaCl_2$  are mixed.

Molecular:  $2Na_3PO_4(aq) + 3CaCl_2(aq) \rightarrow Ca_3(PO_4)_2(s) + 6NaCl(aq)$   
 Full ionic:  $6Na^+(aq) + 2PO_4^{3-}(aq) + 3Ca^{2+}(aq) + 6Cl^-(aq) \rightarrow Ca_3(PO_4)_2(s) + 6Na^+(aq) + 6Cl^-(aq)$

$\Rightarrow$  NET IONIC:  $3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$  net style balance

b) (1 mark) What is the name of the insoluble product that forms?  
 calcium phosphate (insoluble)

c) (3 marks) Calculate the concentration of  $Na^+$  ions in (i) the original 125 mL of  $Na_3PO_4$  solution, and (ii) the supernatant solution after the reaction if the final volume is 1.0 L. Show your work.

(i) originally: 0.50 M  $Na_3PO_4(aq)$  where each 1 mol  $Na_3PO_4$  yields 3  $Na^+(aq)$   
 $\Rightarrow \left(\frac{3 Na^+}{1 Na_3PO_4}\right) \left(\frac{0.50 \text{ mol } Na_3PO_4}{1L}\right) = 1.5 \frac{\text{mol}}{L} Na^+(aq)$

(ii) After the reaction, the  $Na^+$  ions ALL remain dissolved, since  $NaCl$  is soluble. The ions are simply diluted now (total  $V = 1.0L$  instead of  $0.125L$ ).

$n_{Na^+} = \left(\frac{1.50 \text{ mol}}{L}\right) (0.125L) = 0.1875 \text{ mol}$  now in 1.0 L volume  
 $\therefore C_{Na^+} = \left(\frac{0.1875 \text{ mol}}{1.0L}\right) = 0.19 \text{ M}$  -0.25 for SF errors (2 SF due to  $V = 1.0L$ )

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

11

Alternative method:  
(more work than needed)EXTRA SPACE / ROUGH WORK

	mass	mass %	in 100g	(g/mol) MM	moles	normalized ratio	WHOLE # ratio
$MgSO_4 \cdot xH_2O$	4.93g	100%	100g	?	—	—	—
$MgSO_4$	-2.41g	$\frac{2.41}{4.93} \times 100 = 48.88\%$	48.88g	120.38	0.4060	1.000	1
$H_2O$	= 2.52g	$\frac{2.52}{4.93} \times 100 = 51.12\%$	51.12g	18.015	2.839	6.993	7

+ explanation ✓

$\Rightarrow = MgSO_4 \cdot 7H_2O$

Alternate method using mass % :

$$\left\{ \frac{120.38 \frac{g}{mol}}{18.015 \frac{g}{mol}} \right\} = \frac{48.88 \text{ mass \% } MgSO_4}{51.12 H_2O}$$

$$x = 6.99 \approx 7$$

(3SF) (whole #)

+ explanation ✓

(-0.5 SF errors)

$$2.41g = \left( \frac{y}{100} \right) 4.93$$

$$y = 48.88\%$$

$\therefore 51.12\% H_2O$   
by mass.