Name: ____________________ Student number: ______________

**Chemistry 1A03** **Test 1** **Sep 29, 2017**

**McMaster University** **VERSION 1**

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Duration: 90 minutes

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This test contains 16 numbered pages printed on both sides. There are **20** multiple-choice questions appearing on pages numbered 3 to 12. Pages 13 and 14 are extra space for rough work. Page 15 includes some useful data and equations, and there is a periodic table on page 16. You may tear off the last page to view the periodic table and the data provided.

**You must enter your name and student number on this question sheet, as well as on the answer sheet**. Your invigilator will be checking your student card for identification.
**You are responsible** for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

All questions are worth 1 mark - the total marks available are 20. There is **no** penalty for incorrect answers.
**BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.**

**ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.**
Instructions for entering multiple-choice answers are given on page 2.
**SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION** from the answers **(A)** through **(E).** **No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc*.) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only **Casio FX991-MS or FX991-MS+** electronic calculators may be used. They must NOT be transferred between students. Use of any aids other than those provided, is not allowed.

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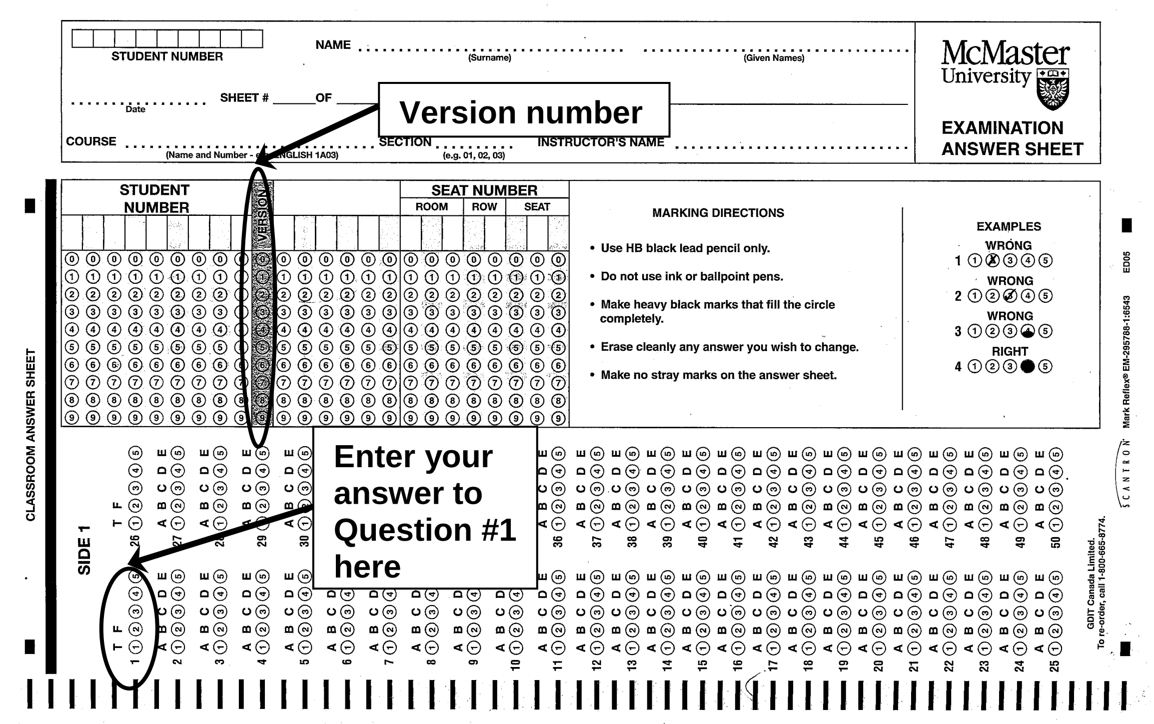
Name: ____________________ Student number: ______________

## OMR EXAMINATION – STUDENT INSTRUCTIONS

**NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.**

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will **NOT** be sensed. Erasures must be thorough or the scanner will still sense a mark. Do **NOT** use correction fluid on the sheets. Do **NOT** put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (**red side**) of the form, in the top box, *in pen*, print your student number, name, course name, and the date in the spaces provided. Then you **MUST** write your signature, in the space marked SIGNATURE.
2. In the second box, *with a pencil*, mark your **student number** in the space provided. If your student number does **NOT** begin with a 4, put "00" before your student number. Then fill in the corresponding bubble numbers underneath.
3. Do NOT put in a leading zero when bubbling in your **exam version number**.
4. Answers: mark only **ONE** choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.
5. Pay particular attention to the marking directions on the form.
6. Begin answering the question using the first set of bubbles, marked "1".

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Name: ____________________ Student number: ______________

1. What is the correct chemical formula for **calcium nitrate?**

A) $CaNO_3$
**B) $Ca(NO_3)_2$**
C) $Ca(NO_2)_2$
D) $Ca_2NO_2$
E) $Ca_2NO_3$

*Calcium is always in the 2+ oxidation state*
*Nitrate is a monoanion (i.e. it has a 1– charge)*

2. A 1.05 kg piece of pure hematite ($Fe_2O_3$) is placed in a 150. L container. At 25.0 °C the container is evacuated to $1.05 \times 10^{-5}$ bar, then filled with 5.05 bar of CO and sealed. The container is heated to 1300 K and the reduction of the hematite to metallic iron goes 100% to completion. The unbalanced reaction is

$$Fe_2O_3\ (s) + CO\ (g) \rightarrow Fe\ (s) + CO_2\ (g) \qquad (\textit{unbalanced})$$

After the vessel has cooled to 25.0 °C, what are (i) **mass of Fe(s) in kg**, (ii) **partial pressure of $CO_2$ (g) in bar**, and (iii) **the total pressure in bar** ?

| | m(Fe) (kg) | P($CO_2$) (bar) | P-total (bar) |
|---|---|---|---|
| **A)** | **0.734** | **3.26** | **5.05** |
| B) | 0.721 | 1.09 | 2.88 |
| C) | 0.721 | 2.17 | 5.05 |
| D) | 0.852 | 3.26 | 4.95 |
| E) | 0.734 | 2.17 | 5.05 |

*Balanced equation = $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$*

*1.05 kg of $Fe_2O_3$ (Molar Mass = 159.7 g $mol^{-1}$) = 1050 g = 6.57 moles*

*Air is removed from the 150. L container (resulting in a good vacuum of $1.05 \times 10^{-5}$ bar)*
*Container is then filled with 5.05 bar of CO at 25 °C*
*$n = PV/RT = (5.05\ bar * 150\ L)/(0.083145\ L\ bar\ K^{-1}\ mol^{-1} * 298.15\ K) = 30.52$ moles*
*CO is therefore present in excess, and $Fe_2O_3$ is the limiting reagent.*

*Moles of Fe produced in the reaction = 2 * 6.57 moles = 13.14 moles*
*Mass of Fe = 13.14 moles * 55.85 = 733.87 g = **0.734 kg***

*Moles of $CO_2$ produced = 3 * 6.57 moles = 19.71 moles*
*$P(CO_2) = nRT/V = (19.71 * 0.083145\ L\ bar\ K^{-1}\ mol^{-1} * 298.15\ K)/150\ L = 3.258 =$ **3.26 bar***

*Total pressure = must stay the same, since for every mole of CO used, 1 mole of $CO_2$ is produced.*
*Therefore, total pressure is still **5.05 bar**.*

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3. A noble gas has a density of 3.425 g $L^{-1}$ at 1.013 bar and 25.0 $^{o}C$. **What is the gas?**

A) He
B) Ne
C) Ar
**D) Kr**
E) Xe

*$PM = dRT$ →*
*$M = dRT/P = (3.425\ g\ L^{-1} * 0.083145\ L\ bar\ K^{-1}\ mol^{-1} * 298.15\ K)/1.013\ bar = 83.7\ g\ mol^{-1}$*
*This is the atomic mass of Krypton.*

4. The density of water, $H_2O(l)$, is 1.0 g/mL. How many **atoms** of hydrogen are present in 2.0 L of pure water?

**A) $1.3 \times 10^{26}$**
B) $1.4 \times 10^{21}$
C) $2.3 \times 10^{22}$
D) $1.5 \times 10^{27}$
E) $2.7 \times 10^{26}$

*2.0 L of water = 2000 ml = 2000 g*
*Moles = 2000 g / 18.015 g $mol^{-1}$ = 111.02*
*Moles of H atoms in 111.02 moles of $H_2O$ = 222.04 moles*
*Atoms of H = moles * $N_A$ = 222.04 moles * $6.022 \times 10^{23}\ mol^{-1} = 1.337 \times 10^{26} = 1.3 \times 10^{26}$ atoms*

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5. Which one of the following atoms or ions has the **greatest number of neutrons** ?

A) $^{12}C$
B) $^{18}F^{-}$
C) $^{18}Ne$
**D) $^{18}O^{2-}$**
E) $^{15}N^{+}$

*The superscripted number in front of the atom symbol is the MASS NUMBER (total # of protons and neutrons). For this question, it is irrelevant whether the atom is neutral, cationic or anionic. From the periodic table, Carbon has 6 protons, F has 9 protons, Ne has 10 protons, O has 8 protons and N has 7 protons. Therefore, the isotopes shown above have the following numbers of neutrons, and the answer is D:*
*A) 6, B) 9, C) 8,* ***D) 10****, and E) 8.*

6. 100.0 g of propyne ($C_3H_4$) (g) is burnt in a 30.0 L rigid vessel containing pure $O_2$ (g) at P = 10.00 bar and an initial temperature of 25.0 °C. At the end of the reaction the temperature of the vessel is 250. °C. At the end of the reaction, what are the **partial pressures (in bar) of $CO_2$ (g)** and **$O_2$ (g)** ?

| | $P(CO_2)$ (bar) | $P(O_2)$ (bar) |
|---|---|---|
| A) | 6.20 | 1.74 |
| B) | 27.6 | 0.00 |
| C) | 10.9 | 2.05 |
| **D)** | **10.9** | **3.07** |
| E) | 5.42 | 16.4 |

*Balanced equation for complete combustion (i.e. the equation if there is enough $O_2$ to completely combust all of the $C_3H_4$ to form $CO_2$ and $H_2O$ with no CO): $C_3H_4 + 4\ O_2 \rightarrow 3\ CO_2 + 2\ H_2O$*

*Molecular mass of propyne = 3 * 12.011 + 4 * 1.0079 = 40.06 g $mol^{-1}$*
*Moles of propyne = 100.0g / 40.06 g $mol^{-1}$ = 2.496 moles*

*Moles of $O_2$, n = PV/RT = (10.00 bar * 30.0 L) / (0.083145 L bar $K^{-1}$ $mol^{-1}$ * 298.15 K) = 12.10 moles $\rightarrow$ $O_2$ is in excess, so propyne is the limiting reagent, and our equation is correct.*

*Moles of $O_2$ remaining = 12.10 - (4 * 2.496) = 2.116 moles*
*Pressure of $O_2$ (at 250 °C) = nRT/V =*
*(2.116 moles * 0.083145 L bar $K^{-1}$ $mol^{-1}$ * 523.15 K)/30 L =* ***3.07 bar***

*Moles of $CO_2$ produced = 3 * 2.496 moles = 7.488 moles*
*Pressure of $CO_2$ (at 250 °C) = nRT/V =*
*(7.488 moles * 0.083145 L bar $K^{-1}$ $mol^{-1}$ * 523.15 K)/30 L = 10.857 bar =* ***10.9 bar***

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7. An orbital has the following quantum numbers

   $n = 5, \quad \ell = ?, \quad m_\ell = -2$

   What are the possible value(s) of the $\ell$ **quantum number** ?

   A) 5, 4, 3, 2 or 1
   B) 5, 4, 3 or 2
   C) 4 only
   **D) 4, 3 or 2**
   E) 4, 3, 2 or 1

*If n = 5, l can be equal to 0, 1, 2, 3 or 4.*
*However, if $m_l$ = -2, l must be greater than or equal to 2.*
*Therfore, the possible values for l are 4, 3, or 2.*

8. For one CO molecule to go from one energy level to another, higher energy level requires the absorption of light with a frequency of $1.16 \times 10^{11}$ Hz. What is the **energy in kJ mol$^{-1}$** required for this transition?

   A) $7.96 \times 10^{-23}$
   **B) $4.63 \times 10^{-2}$**
   C) $1.03 \times 10^{-12}$
   D) $1.39 \times 10^{10}$
   E) $1.28 \times 10^{-6}$

*Energy (J) for this transition = $h\nu = 6.6256 \times 10^{-34}$ Js * $1.16 \times 10^{11}$ Hz = $7.686 \times 10^{-23}$ J*
*This is for one molecule of CO. For a mole of CO, we need to multiply by $N_A$.*
*Energy (kJ mol$^{-1}$) = $7.686 \times 10^{-23}$ J * $6.022 \times 10^{23}$ mol$^{-1}$ = 46.28 J mol$^{-1}$ = $4.63 \times 10^{-2}$ kJ mol$^{-1}$*

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9. A **doubly charged atomic cation** in an **excited state** has the following electron configuration:

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ 4s^1$

The species is:

A) $K^{2+}$
**B) $Ca^{2+}$**
C) $Sc^{2+}$
D) $Ar^{2+}$
E) $Cl^{2+}$

*We are given a configuration for an $M^{2+}$ dication in an excited state.*
*The ground state configuration for this dication must be $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$*
*Only $Ca^{2+}$ will have this ground state configuration.*

10. Which of the following atoms in their ground state are **paramagnetic** (i.e. have unpaired electrons)?

C, O, Mg, Al, P

A) Only P
B) Al and P
C) C, Al and P
**D) C, O, Al and P**
E) C, O, Mg, Al and P

*Only Mg has no unpaired electrons.*

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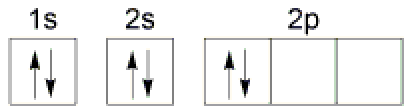
Name: ____________________ Student number: ______________

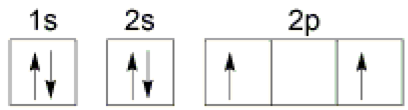
11. Consider the following orbital filling diagrams:

I 

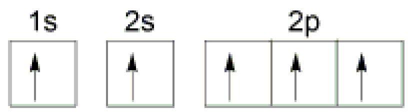
*need to fill all 2p orbitals with 1 electron each, before starting to pair up electrons*

II 

*two electrons in same orbital with same spin not allowed*

III 

*this is fine*

IV 

*completely fill 1s before putting electrons in 2s; completely fill 2s before putting electrons in 2p*

Which orbital filling diagram(s) represent a **valid ground-state configuration** of an atom ?

A) I and II
B) II and III
**C) III only**
D) I and IV
E) IV only

*See above.*

12. Potassium has a threshold energy of $2.92 \times 10^{-18}$ J. When light with a wavelength of 38.8 nm is shone on a potassium surface, with what **velocity** (**in m s$^{-1}$**) will photoelectrons be ejected?

**A) $2.20 \times 10^6$**
B) $5.13 \times 10^8$
C) $2.43 \times 10^{12}$
D) $1.56 \times 10^9$
E) Photoelectrons will not be ejected.

$E_{incident} = hc/\lambda = (6.6256 \times 10^{-34}\ Js * 2.9979 \times 10^8\ m/s)/3.88 \times 10^{-8}\ m = 5.12 \times 10^{-18}\ J$
Kinetic Energy $= E_{incident} - E_{threshold} = 5.12 \times 10^{-18}\ J - 2.92 \times 10^{-18}\ J = 2.20 \times 10^{-18}\ J$

$KE = \frac{1}{2} mu^2 \rightarrow u = SQRT\ (2\ KE / m)$
$= SQRT\ [(2 * 2.20 \times 10^{-18}\ J) / 9.109 \times 10^{-31}\ kg] = 2.20 \times 10^6\ J$

13. An electron in a hydrogen atom undergoes a transition from n = 2 to n = 3. Which of the following two statements are **FALSE**?

(i) A photon is emitted in the transition.
(ii) The atom started out in an excited state.
(iii) Light with a wavelength of 656 nm has the same energy as this transition.
(iv) The frequency of light for the transition from n = 2 to n = 3 is higher than the frequency of light for the transition from n = 1 to n = 2.

A) i and ii
B) iii and iv
C) i and iii
D) ii and iii
**E) i and iv**

*(i) FALSE, since this transition will require energy, rather than releasing energy.*
*(ii) TRUE, since a hydrogen atom has just 1 electron and in the ground state, n=1, not 2.*
*(iii) TRUE (see below)*
(iv) *FALSE, $\Delta E$ for an n=2 to n=3 transition is smaller than that for an n=1 to n=2 transition. Therefore, the frequency of light absorbed to effect this transition will be lower.*

*For n = 2, $E = -R_H/n^2 = -2.179 \times 10^{-18}$ J / 4 = $-5.448 \times 10^{-19}$ J*
*For n = 3, $E = -R_H/n^2 = -2.179 \times 10^{-18}$ J / 9 = $-2.421 \times 10^{-19}$ J*
*$\Delta E = 3.027 \times 10^{-19}$ J*

*$E = hc/\lambda \rightarrow \lambda = hc/E = (6.6256 \times 10^{-34}\ \text{Js} * 2.9979 \times 10^{8}\ \text{m/s}) / 3.027 \times 10^{-19}\ \text{J}$*
*$= 6.56 \times 10^{-7}$ m = 656 nm*

14. Select the two **most electronegative** atoms from the following list:

Be, Br, **Cl**, Na, **O**

A) Na and Be
B) Na and Cl
C) O and Br
**D) O and Cl**
E) Br and Cl

*Elements are more electronegative towards the top right of the periodic table.*

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15. Arrange the following species from **largest to smallest radius**:

$S^{2-}$, $Al^{3+}$, Cl, Si, $Mg^{2+}$, Mg

**A)** $S^{2-}$ Mg Si Cl $Mg^{2+}$ $Al^{3+}$
B) Mg $Mg^{2+}$ $Al^{3+}$ Si $S^{2-}$ Cl
C) $S^{2-}$ Mg $Mg^{2+}$ Si Cl $Al^{3+}$
D) $S^{2-}$ $Mg^{2+}$ $Al^{3+}$ Mg Si Cl
E) Mg Si Cl $S^{2-}$ $Mg^{2+}$ $Al^{3+}$

*All are elements or ions from the 3rd period.*
*Largest will be the $S^{2-}$ dianion due to the charge*
*Smallest will be $Al^{3+}$ due to the charge, followed by $Mg^{2+}$*
*For the neutral elements, size will decrease across the period, so Mg > Si > Cl.*

16. Which one of the following statements is **FALSE** ?

**A) The magnitude of the electron affinity of P is larger than that of Si**
B) The atomic radius of Li is smaller than that of Na
C) The first ionization energy of Mg is larger than that of Al
D) The metallic character of Rb is greater than that of K
E) The value of $Z_{eff}$ for the outermost valence electrons is larger for Xe than for Rb

*A) FALSE, P has a half-filled subshell, so is reluctant to accept another electron.*
*B) TRUE, Li is smaller than Na since it is in the 2nd period, not the 3rd period.*
*C) TRUE, it will require more energy to remove an electron from Mg because it has a completely filled s-shell.*
*D) TRUE, metallic character increases towards the bottom left of the periodic table.*
*E) TRUE, $Z_{eff}$ increases across a period because the valence electrons do not shield their neighboring valence electrons very effectively from the increasing nuclear charge (Z).*

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17. What is the **magnitude of the energy <u>difference</u> (in kJ)** required to ionize 2.00 g of Cs versus 2.00 g of Rb ? The ionization energies of Cs and Rb are 375.7 kJ $mol^{-1}$ and 403.0 kJ $mol^{-1}$, respectively.

A) 27.3
**B) 3.78**
C) 14.2
D) 94.8
E) 54.6

*2.0g of Cs = 2 g / 132.91 g $mol^{-1}$ = 1.505 x $10^{-2}$ moles*
*Energy required to ionize 2g of Cs = 375.7 kJ $mol^{-1}$ * 1.505 x $10^{-2}$ moles = 5.654 kJ*

*2.0g of Rb = 2 g / 85.468 g $mol^{-1}$ = 2.340 x $10^{-2}$ moles*
*Energy required to ionize 2g of Rb = 403.0 kJ $mol^{-1}$ * 2.340 x $10^{-2}$ moles = 9.430 kJ*

*Energy difference = 9.43 – 5.65 = 3.78 kJ*

18. The ground state of two elements, A and B, have the following electron configurations:

A = $[He]2s^22p^5$ B = $[Ne]3s^23p^1$

Which one of the following statements regarding these two elements is **FALSE** ?

**A) Element A has more metallic character than element B**
B) Element A has a smaller atomic radius than element B
C) Element A has a higher magnitude of electron affinity than element B
D) Element A has a higher first ionization energy than element B
E) In atomic form, elements A and B are both paramagnetic (i.e. have unpaired electrons)

*Based on the ground state electronic configurations,*
*Element A = Fluorine, and*
*Element B = Aluminum*

*A) FALSE, F is not more metallic than Al.*
*B) TRUE, F has a smaller atomic radius than Al (2p vs 3p, and further to the right hand side)*
*C) TRUE, F has a much higher electron affinity than Al (it really wants to become $F^-$)*
*D) TRUE, ionization energy increases across a period.*
*E) TRUE, both F and Al will have one unpaired electron.*

19. When the following atoms are ranked from **highest to lowest first ionization energy**, which atom falls in the **middle** of the series**:**

B, Be, C, F, Na

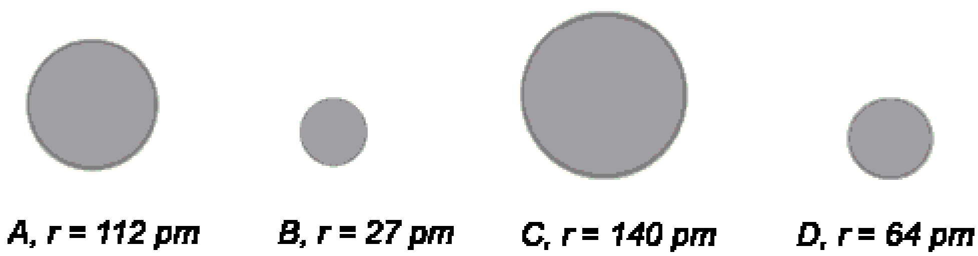
**A) Be**
B) Na
C) C
D) F
E) B

*Except for Na, all are 2p elements.*
*Ionization energy increases towards the top right of the periodic table.*
*Ignoring blips, we would have F > C > B > Be > Na. HOWEVER, B has a higher tendency to lose an electron in order to gain a completely filled 2s-shell, and Be really does not want to lose an electron since it already has a completely filled 2s-shell. Therefore, the order of B and Be is flipped, and the correct order is:*
*F > C >* ***Be*** *> B > Na.*

20. The following four spheres represent Be, $Be^{2+}$, O and $O^{2-}$ (not necessarily in that order).

*Based on sizes ($O^{2-}$ > Be > O > $Be^{2+}$), the different atoms/ions are:*

*A = Be* *B = $Be^{2+}$* *C = $O^{2-}$* *D = O*




Which pair **of reactions** is most consistent with the **relative sizes of these species** ?

**A) $A \rightarrow B + 2e^-$ and $D + 2e^- \rightarrow C$**
B) $A \rightarrow C + 2e^-$ and $D + 2e^- \rightarrow B$
C) $A \rightarrow D + 2e^-$ and $C + 2e^- \rightarrow B$
D) $A + 2e^- \rightarrow C$ and $D \rightarrow B + 2e^-$
E) $A + 2e^- \rightarrow B$ and $C \rightarrow D + 2e^-$

*Now that we have identified A, B, C, and D, only answer A makes sense (i.e. Be → $Be^{2+}$ + $2e^-$ and O + $2e^-$ → $O^{2-}$)*

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**Extra space for rough work**

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## Extra space for rough work

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Name: ____________________ Student number: ______________

- **Some general data are provided on this page.**
- **A Periodic Table with atomic weights is provided on the next page.**

STP = 273.15 K, 1 atm

$N_A = 6.022 \times 10^{23}$ mol$^{-1}$

$h = 6.6256 \times 10^{-34}$ Js

density($H_2O$, l) = 1.00g/mL

Specific heat of water = 4.184 J / g·°C

$R = 8.3145$ J K$^{-1}$ mol$^{-1}$ = 0.08206 L atm K$^{-1}$ mol$^{-1}$ = 0.083145 L bar K$^{-1}$ mol$^{-1}$

$F$ = 96485 C/mol

$c = 2.9979 \times 10^{8}$ m/s

$m_e = 9.109 \times 10^{-31}$ kg

$\Delta H^o_{vap}[H_2O]$ = 44.0 kJ mol$^{-1}$

1 bar = 100.00 kPa = 750.06 mm Hg = 0.98692 atm

1 J = 1 kg m$^2$ s$^{-2}$ = 1 kPa L = 1 Pa m$^3$

1 cm$^3$ = 1 mL

1 Hz = 1 cycle/s

0°C = 273.15 K

1 m = $10^6$ μm = $10^9$ nm = $10^{10}$ Å

1 g = $10^3$ mg

De Broglie wavelength:

$\lambda = h / mu = h / p$

Hydrogen atom energy levels:

$E_n = -R_H / n^2 = -2.179 \times 10^{-18}$ J / $n^2$

$KE = ½mu^2$

Nernst Equation:

$$E = E° - \frac{RT}{zF}\ln Q \quad = E° - \frac{0.0257\ \text{V}}{z}\ln Q \quad = E° - \frac{0.0592\ \text{V}}{z}\log_{10} Q$$

Entropy change: $\Delta S = \dfrac{q_{rev}}{T}$

**Solubility Guidelines for Common Ionic Solids**

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations and the $NH_4^+$ cation are soluble . Except LiF and $Li_2CO_3$ which are insoluble.
2. Nitrates, acetates, bicarbonates, and perchlorates are soluble.
3. Salts of silver, lead and mercury (I) are insoluble. Except AgF which is soluble.
4. Fluorides, chlorides, bromides, and iodides are soluble. Except Group 2 fluorides which are insoluble
5. Carbonates, phosphates, chromates, sulfides, oxides, and hydroxides are insoluble. Except Group 2 sulfides and hydroxides of $Ca^{2+}$, $Sr^{2+}$, and $Ba^{2+}$ which are soluble.).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

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Name: ____________________ Student number: ______________

# PERIODIC TABLE OF THE ELEMENTS

| I 1 | II 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | III 13 | IV 14 | V 15 | VI 16 | VII 17 | VIII 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.0079 | | | | | | | | | | | | | | | | | 2 He 4.0026 |
| 3 Li 6.941 | 4 Be 9.0122 | | | | | | | | | | | 5 B 10.811 | 6 C 12.011 | 7 N 14.007 | 8 O 15.999 | 9 F 18.998 | 10 Ne 20.180 |
| 11 Na 22.990 | 12 Mg 24.305 | | | | | | | | | | | 13 Al 26.982 | 14 Si 28.086 | 15 P 30.974 | 16 S 32.066 | 17 Cl 35.453 | 18 Ar 39.948 |
| 19 K 39.098 | 20 Ca 40.078 | 21 Sc 44.956 | 22 Ti 47.88 | 23 V 50.942 | 24 Cr 51.996 | 25 Mn 54.938 | 26 Fe 55.847 | 27 Co 58.933 | 28 Ni 58.69 | 29 Cu 63.546 | 30 Zn 65.39 | 31 Ga 69.723 | 32 Ge 72.61 | 33 As 74.922 | 34 Se 78.96 | 35 Br 79.904 | 36 Kr 83.80 |
| 37 Rb 85.468 | 38 Sr 87.62 | 39 Y 88.906 | 40 Zr 91.224 | 41 Nb 92.906 | 42 Mo 95.94 | 43 Tc [98] | 44 Ru 101.07 | 45 Rh 102.91 | 46 Pd 105.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.71 | 51 Sb 121.75 | 52 Te 127.60 | 53 I 126.90 | 54 Xe 131.29 |
| 55 Cs 132.91 | 56 Ba 137.33 | 57 *La 138.91 | 72 Hf 178.49 | 73 Ta 180.95 | 74 W 183.85 | 75 Re 186.21 | 76 Os 190.2 | 77 Ir 192.22 | 78 Pt 195.08 | 79 Au 196.97 | 80 Hg 200.59 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.98 | 84 Po [209] | 85 At [210] | 86 Rn [222] |
| 87 Fr [223] | 88 Ra 226.03 | 89 **Ac 227.03 | 104 Unq [261] | 105 Unp [262] | 106 Unh [263] | | | | | | | | | | | | |

Transition Metals (groups 3–12)

Atomic weights are based on $^{12}C$ = 12 and conform to the 1987 IUPAC report values rounded to 5 significant digits. Numbers in [ ] indicate the most stable isotope.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Lanthanides | 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm [145] | 62 Sm 150.36 | 63 Eu 151.97 | 64 Gd 157.25 | 65 Tb 158.93 | 66 Dy 162.50 | 67 Ho 164.93 | 68 Er 167.26 | 69 Tm 168.93 | 70 Yb 173.04 | 71 Lu 174.97 |
| ** Actinides | 90 Th 232.04 | 91 Pa 231.04 | 92 U 238.03 | 93 Np 237.05 | 94 Pu [244] | 95 Am [243] | 96 Cm [247] | 97 Bk [247] | 98 Cf [251] | 99 Es [252] | 100 Fm [257] | 101 Md [258] | 102 No [259] | 103 Lr [262] |

**END OF EXAM**